This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google™ books

https://books.google.com

UC-NRLF
$B 251 417

Berkeley
LIBRARY OF THE UNIVERSITY OF CALIFORNIA

LIBRARY OF THE UNIVERSITY OF CALIFORNIA · Berkeley

AVIATION ORDNANCEMAN 1&C

NAVY
TRAINING
COURSES

AVIATION ORDNANCEMAN 1 & C

Prepared by

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSES

NAVPERS 10347

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1958

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. — Price $1.75

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

VG93
A3347

PREFACE

This NAVY TRAINING COURSE is one of a series of courses written especially for the Aviation Ordnanceman. Its contents are based on the qualifications for advancement to the rates of Aviation Ordnanceman, First Class, and Chief Aviation Ordnanceman. It is to be used as a source of information for the Aviation Ordnanceman Second Class or First Class, in qualifying for advancement to First Class or Chief Aviation Ordnanceman, and as a review source for the Chief Aviation Ordnanceman. The aviation ordnance qualifications used as minimum requirement guide lines for the preparation of this course are to be found in the *Manual of Qualifications for Advancement in Rating,* NavPers 18068 (Revised). These same qualifications are also reproduced in appendix III of this course for the sake of convenience. THEY ARE CURRENT THROUGH CHANGE 8 TO THE MANUAL.

Beginning with an introductory chapter, the course continues with other chapters concerning ballistics; gun systems; boresighting; linking and delinking equipment; turret systems; suspension, arming, and releasing systems; bombing equipment; small arms ranges; and munitions handling and stowage methods. The last two chapters contain information on administration and training and supervisory techniques.

Aviation Ordnanceman 1 & C has been prepared by the United States Navy Training Publications Center, Memphis, Tennessee, and the Training Division of the Bureau of Naval Personnel. Credit is also given to the Aviation Ordnanceman School, Jacksonville, Florida, for preparation of the end-of-chapter questions which constitute a review of the contents of each chapter of this course.

ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
SERVICE	4 mos. service—or completion of recruit training.	6 mos. as E–2 or 8 mos. total service.	6 mos. as E–3 or 14 mos. total service.	12 mos. as E–4.	12 mos. as E–5; total service at least 36 mos.	36 mos. as E–6.
SCHOOL	Recruit Training.		Class A for PR3, PRS3.		Class B for MN1.	Class B for AGCA, MNCA, MUCA.
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.			
PRACTICAL FACTORS	Locally prepared check-offs.	Records of Practical Factors, NavPers 760, must be completed for E–3 and all PO advancements.				
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.			
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.			
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Required for E–3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed.				
AUTHORIZATION	Commanding Officer		U. S. Naval Examining Center			BuPers
	TARS are advanced to fill vacancies and must be approved by district commandants or CNARESTRA.					

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
	FOR THESE DRILLS PER YEAR						
TOTAL TIME IN GRADE	24 OR 48	9 mos.	9 mos.	15 mos.	18 mos.	24 mos.	36 mos.
	12	9 mos.	15 mos.	21 mos.	24 mos.	36 mos.	42 mos.
	NON-DRILLING	12 mos.	24 mos.	24 mos.	36 mos.	48 mos.	48 mos.
DRILLS ATTENDED IN GRADE#	48	27	27	45	54	72	108
	24	16	16	27	32	42	64
	12	8	13	18	20	32	38
TOTAL TRAINING DUTY IN GRADE#	24 OR 48	14 days	14 days	14 days	14 days	28 days	42 days
	12	14 days	14 days	14 days	28 days	42 days	42 days
	NON-DRILLING	None	None	14 days	14 days	28 days	28 days
PERFORMANCE TESTS				Specific ratings must complete applicable performance tests before taking examination.			
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 1316, must be completed for all advancements.					
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.					
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.					
AUTHORIZATION		District commandant or CNARESTRA					BuPers

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

#Active duty periods may be substituted for drills and training duty.

READING LIST

NAVY TRAINING COURSES

Blueprint Reading and Sketching, NavPers 10077–A
Basic Hand Tool Skills, NavPers 10085
Basic Electricity, NavPers 10086
Aviation Ordnanceman 3 & 2, Volume 1, NavPers 10345
Aviation Ordnanceman 3 & 2, Volume 2, NavPers 10346

USAFI TEXTS

The United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education Officer.* A partial list of those courses applicable to your rate follows:

Number	**Title**
	Correspondence
CB 781	*Fundamentals of Electricity*
CB 836	*Machine Shop II*
CC 291	*Physics II*
CA 860	*Elements of Mechanics*
	Self-Teaching
MB 781	*Fundamentals of Electricity*
MB 836	*Machine Shop II*
MC 291	*Physics II*

*"Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more or if they have been on active duty for a period of 120 days or more, regardless of the time specified in the active duty orders."

CONTENTS

Chapter

Page

1. Introduction ---------------------------------- 1
2. Aviation ballistics -------------------------- 28
3. Aircraft gun systems ------------------------- 70
4. Aircraft boresighting ----------------------- 126
5. Linking and delinking equipment ------------ 183
6. Aircraft turret systems --------------------- 226
7. Suspension, arming, and releasing systems --- 319
8. Bombing equipment --------------------------- 343
9. Small arms ranges --------------------------- 373
10. Ammunition handling and stowage methods --- 417
11. Administration ----------------------------- 473
12. Training and supervisory techniques for aviation ordnance ------ 501

Appendix

I. Electronic parts symbols ------------------- 523
II. Answers to quizzes ------------------------ 525
III. Qualifications for advancement in rating -- 529

Index -- 537

STUDY GUIDE

The table below indicates which chapters of this book apply to your rating. To use the table, follow these rules:

1. Select the column that applies to your rating. If you are advancing in the General Service Rating, you will use the column headed "AO". If you are advancing in one of the Emergency Service Ratings, you will use either the column headed "AOT" or "AOU".

2. Observe which chapters have been marked in the rating column for your particular rate.

3. Study those particular chapters. They include information which will assist you in meeting the qualifications for your rating. In order to gain a well-rounded view of the duties of the General Service Rating, it is recommended that you read the other chapters of this book even though they do not pertain directly to your rating.

4. Here is an example: If you are advancing to AOU1 you will select the column headed AOU. Following this column down you will observe that you must study chapters 1, 3, 4, 7, 10, 11, and 12.

Chapter	AO	AOT	AOU
1	1	1	1
2	C	C	C
3	1	1	1
4	1	1	1
5	C		C
6	1	1	
7	1	1	1
8	1		
9	C		C
10	1	1	1
11	1	1	1
12	1	1	1

AVIATION ORDNANCEMAN 1 & C

OBJ

maj
Cla
fr
he f
p
m
arn
as o
and
l in
y.
cour
sion,
s; bo
vices
g ar
and s
g sta
he J
rega
will
ourse
hapter
ing
ext ch
cted t
retain

CHAPTER 1

INTRODUCTION

OBJECTIVES AND CONTENT OF THE COURSE

The major objectives of this course are to afford the Second Class Aviation Ordnanceman one particular publication from which to study for advancement to first class, the first class to advance to chief petty officer, and the chief petty officer to have a ready source of information from which to refresh his memory on details previously learned. Materials covered in this course deal with the areas of work and responsibility common to the First Class and Chief Aviation Ordnanceman, respectively, as outlined in the *Manual of Qualifications for Advancement in Rating*, NavPers 18068 (Revised).

The course contains information on turret systems; suspension, arming, and releasing systems; aircraft gun systems; boresighting guns and sights; ammunition belting devices; bombing equipment; small arms ranges; training and supervisory techniques; ammunition handling and stowage; administration; and appendices indicating standard electronics parts symbols, and extracts from the *Manual of Qualifications for Advancement in Rating* regarding the aviation ordnance rating.

You will find that much more of the information in this course will be retained if you will carefully read one chapter and then answer the objective type questions appearing at the end of the chapter BEFORE you go to the next chapter. Repeat this procedure until you have completed the course. Then, to find out how much you have retained from the course as a whole, go back and attempt to answer all of the questions again for all chapters. In the event that there are some that you cannot answer, reread the pertinent chapters. In this way you will receive the maximum benefit from the course.

ORDNANCE ORGANIZATION

The modern naval combat aircraft is no longer merely a "gun platform" to which the ordnance and armament gear is added. This modern combat aircraft is a highly integrated weapon built around the guns, fire control system, and stowage spaces for munitions, with great attention given to weight, space saving and integration of equipment for specific types of missions.

As weapons of aerial warfare advance in efficiency and effectiveness, they invariably increase in complexity. You, as Aviation Ordnancemen currently have to master some of the most complicated and intricate equipment used by the Navy. A look into the future shows no signs of lessening complexity in aviation ordnance equipment—quite the contrary. Your formal schooling has prepared you to work with present-day equipment through intimate association with most types and classes. However, new ideas, new planning, an increased emphasis on aerial warfare are bringing about such radical changes to the equipment now current, that you can ill afford to let up even momentarily in your efforts to keep abreast of advances in aviation ordnance. Even at the present time, Aviation Ordnancemen have to know the fundamentals of electricity, hydraulics, and other fields in order to perform their duties successfully. There is no way of knowing what additional fields will be disclosed for the Aviation Ordnanceman in the future, but you will become a part of these new and exciting fields. There is no doubt that the Aviation Ordnanceman has an exciting future in store.

Some of the latest ideas and equipment cannot be incorporated into this course due to classification restrictions and the impossibility of producing an up-to-the-minute course on a subject which changes so rapidly. It will be up to you to fill in the void between this course and the latest in aviation ordnance and armament equipment by reading and studying all of the recent publications available on the subject. Whenever possible, you should study the new gear itself. Never take it for granted that the gear with which you are working is the ultimate, because a newer piece will appear. It will probably be even more complicated. Learn all you can, but keep an open mind about coming events. If you understand all there is to be known about a piece of gear that has been superseded by a newer one, the new one will be much easier to comprehend. Continually search out and study publications concerning aviation ordnance and armament—commercial as well as service publications.

The Aviation Ordnance Rates

This course has been prepared to cover the professional requirements for the general service rates of Aviation Ordnanceman (AO)1 & C, and the TWO emergency service rates Aviation Ordnanceman Utility (AOU) 1 & C and Aviation Ordnanceman Turrets (AOT) 1 & C. The military requirements for these rates are in the *Manual of Qualifications for Advancement in Rating,* NavPers 18068 (Revised) and as printed in the *General Training Course for Petty Officers,* NavPers 10055.

The professional qualifications listed in the above publications are the minimum required for enlisted personnel to perform properly the duties of a particular rate or rating. The military requirements are those general qualifications applicable to all enlisted personnel who are expected to demonstrate them as a minimum for advancement to specific pay grades. You will note that those requirements applicable to men and women are so designated.

The AVIATION ORDNANCEMAN (AO) is responsible for maintenance, repair, removal, operation, servicing, and handling of all small arms and aviation ordnance equipment. This equipment includes aircraft guns, turrets, power gun mounts, rocket launchers, suspension and releasing mechanisms, and pyrotechnic, tow target, and munitions handling equipment. He is further responsible for operating and performing routine servicing and checking of aviation gun, bomb, and rocket sights; stowing, maintaining, servicing, handling, installing, and removing aviation munitions and pyrotechnics; and for maintaining and operating a small arms range.

The AVIATION ORDNANCEMAN UTILITY (AOU) is responsible for maintaining, servicing, removing, repairing, installing, operating, and handling of all small arms and aviation ordnance equipment. This equipment includes aircraft guns, rocket launchers, suspension and releasing devices, pyrotechnics, tow target, and munition handling equipment. He will operate and perform routine servicing and checking of aviation gun, bomb, and rocket sights; stow, maintain, service, handle, install, and remove aviation munitions and pyrotechnics; and maintain and operate small arms ranges.

The AVIATION ORDNANCEMAN TURRETS (AOT) is basically responsible for maintaining, servicing, removing, repairing, installing, and operating aircraft turrets and powered gun mounts.

Selective Emergency Service Rates Program

The Selective Emergency Service Rates Program (SESR Program) has been instituted by the Navy to facilitate and more completely specialize the training of naval personnel in the lower pay grades. This program is a specialized training plan aimed at obtaining the fullest use of personnel under the Navy training programs and to meet the fleet needs. This program concerns the aviation ordnance rating in that the aviation ordnance striker may no longer advance to the general service rate of AO3. He now must advance to one or the other emergency service rates, i.e., AOU3 or AOT3. This applies to the Regular Navy personnel and Naval

Reserve personnel alike. Personnel now accomplish the advancement to AOU3 and AOT3 because of their specialization during basic training through the activation of the emergency service rates. The Group IX ratings (aviation) are especially adapted to the SESR Program due to the fact that aviation, along with some other fields, have advanced so spectacularly in recent years.

Bureaus and Offices

In order to better understand your role as an Aviation Ordnanceman, let us briefly review the applicable parts of the Navy organization most closely associated with your rating. At the top level under the Secretary of the Navy there are two bureaus which have cognizance over aircraft armament and ordnance. These are the Bureau of Aeronautics and the Bureau of Ordnance.

The BUREAU OF ORDNANCE (BuOrd) is charged with the responsibility of design, manufacture, procurement, maintenance, issue, and efficiency of all offensive and defensive weapons and armament as well as devices and optics for control of guns, torpedoes, and bombs. In addition, this Bureau is charged with the responsibility of upkeep and operation of all naval ordnance establishments. (See fig. 1–1.)

You have already heard of the PLANNING AND PROGRESS, the MATERIAL, and the RESEARCH AND DEVELOPMENT DIVISIONS of the Bureau of Ordnance, as these divisions are the ones most closely associated with aviation ordnance. The Planning and Progress Division is concerned with the complete cycle of BuOrd duties from

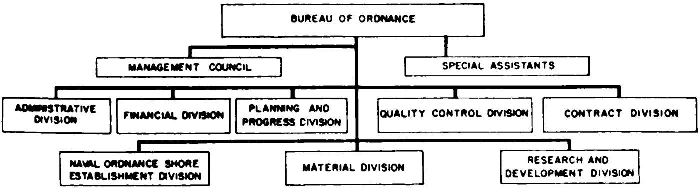


Figure 1–1.—Organization of the Bureau of Ordnance.

the acceptance of a task to its successful completion. This division assigns the work to the other divisions, specifies what is to be done, and who is to do the work. The Material Division takes the previously released pilot production models of equipment all the way through production, procurement, distribution, installation, maintenance, repair, and overhaul. The Research and Development Division is responsible for a weapon program from the first idea, development, experiment, and design, through the prototype construction and test stages, up to the final design of the production model. Each of the above divisions has within its framework an AVIATION ORDNANCE BRANCH. These branches are concerned with the items and work peculiar to aviation ordnance.

The BUREAU OF AERONAUTICS (BuAer) is responsible for design, construction, test, procurement, production, maintenance and repair of all naval aircraft as well as all aeronautical materials related thereto. It looks after the aeronautical shore facilities and furnishes aircraft and aeronautical materials. (See fig. 1–2.)

There are many offices, divisions, and sections of the Bureau of Aeronautics. However, the offices which you will normally hear more about are the ASSISTANT CHIEF FOR DESIGN AND ENGINEERING, the ASSISTANT CHIEF FOR RESEARCH AND DEVELOPMENT, and the ASSISTANT CHIEF FOR MATERIAL AND SERVICES. These are the offices of the Bureau of Aeronautics directly concerned with aviation ordnance.

It is well to mention briefly here the function of the Deputy Chief of Naval Operations for Air, or DCNO (Air). This office has become most important since it was established in 1943. The mission of this office is "to correlate and coordinate all military aspects, including policies, plans, and logistics of naval aviation, including the Naval Reserve, and development of guided missiles." Think of the rapid evolution and growth of aerial warfare in the last few years and you will begin to realize the importance of this office.

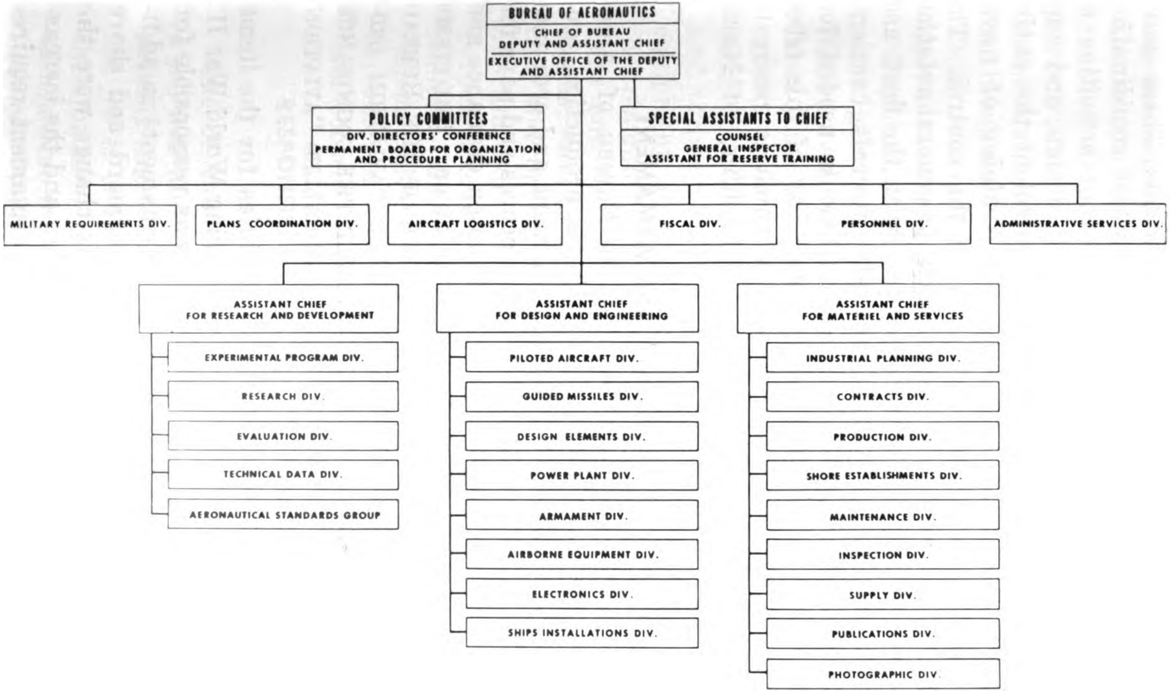


Figure 1—2.—Organization of the Bureau of Aeronautics.

DCNO(Air) sets naval aircraft and armament requirements, and is responsible for preparation, readiness, and logistic support of all naval aviation. These goals could not be attained without the closest coordination of the aviation ordnance and armament activities of BuOrd and BuAer regarding research, design, and supply. DCNO(Air) centralizes the control of the entire aeronautical branch of the Navy. Training of naval aviators and aircrewmen is included in this control. The Deputy Chief aids in the development of general aviation policies, coordinates aviation matters with the fleet, and establishes the number of aircraft, aircraft carriers, auxiliary vessels, and shore establishments needed for all missions. It is also the responsibility of this office to assure an aviation organization which is ready to perform the missions assigned by the Chief of Naval Operations.

AIRBORNE ORDNANCE AND ARMAMENT

The Bureau of Ordnance and the Bureau of Aeronautics have a joint responsibility in the production, procurement, and issue of aviation armament and ordnance equipment. Each of these bureaus procures and pays for all of the offensive and defensive aviation ordnance and armament under their respective cognizance. THE ITEMS OF EQUIPMENT UNDER THE COGNIZANCE OF THE BUREAU OF ORDNANCE ARE GENERALLY CALLED "AVIATION ORDNANCE EQUIPMENT," AND THOSE UNDER THE COGNIZANCE OF THE BUREAU OF AERONAUTICS ARE CALLED "AVIATION ARMAMENT EQUIPMENT."

The present division of responsibilities for the items under the two bureaus came about during World War II. Previously, the Bureau of Ordnance was responsible for most of the aviation ordnance (and armament) in addition to such equipment used by shipboard and shore activities. The basic reasons for this change were the rapid evolution in naval aircraft design and the increasing complexity of the ordnance and armament requirements of the combat aircraft itself. There had to be a common meeting ground between those who designed the aircraft and those who designed the ordnance and armament for these aircraft. If we were to have unexcelled firepower incorporated into our aircraft, the aircraft had to be built around the ordnance and armament equipment. This brought into being a new concept in integrated design for combat aircraft; a concept which was a planned outgrowth of close and efficient liaison between the two bureaus.

Cognizance over specific items of ordnance and armament gear is sometimes shifted between BuAer and BuOrd even today. However, as a general rule, BuAer takes care of certain guns, accessories and controls, turrets, power turrets (remotely controlled), bomb racks, bomb shackles, all releasing system equipment, bomb and torpedo handling equipment, smoke and chemical equipment, armor for aircraft, and rocket launchers of the nongun type. BuOrd generally has control over guns and certain accessories, recoil absorbing mounts, bombs, mines, torpedoes, rockets, ammunition, fire control and optical equipment, pyrotechnics (expendable and gun-type dischargers), chemical and smoke items (expendable only), bomb cranes, cargo trucks, and bomb trailers. BuAer and BuOrd have a joint control and responsibility over all towed targets. Each of these bureaus has control over certain guided missiles and joint control over others.

RESPONSIBILITIES AND IMPORTANCE OF WORK

Practical Leadership

One of the greatest personal satisfactions is to do a job well and on time. You may not realize this while actually engrossed in completing the job. However, once the job is completed and you have a chance to survey the situation, you at once have a feeling of pride and satisfaction in noting that the job has been properly handled. When you were a third class petty officer, you undoubtedly had this feeling as you and your shipmates took a breather after rearming a strike or sweep in record time. As a second or first class petty officer, you too must have experienced this feeling, but for a different reason.

It is now that you realize YOU ARE THE ONE RESPONSIBLE for the training of the men, organizing all efforts, and assuring that each phase of the work went AS YOU HAD PLANNED IT, so that the rearming took place to the satisfaction of all concerned. It is a challenge to your mental and physical capabilities. Any hard job is a challenge. But when you realize the results that have been brought about by your own supervision, you feel amply repaid for all your efforts.

Since becoming a second or first class petty officer, you have found that your job has changed considerably. Very seldom do you expend the same amounts of physical effort in the daily work you previously did. You have become a supervisor, a teacher, an organizer, a personnelman, and a leader. You were selected for these new responsibilities because your past performances had proven your native abilities. As a matter of fact, you are in an enviable position in being able to supervise, teach, and lead those under you. You are now in a position to put into practical use all of the things you learned the hard way through experience. You will probably be the first to admit that, with these new responsibilities added to your duties, you have found a certain self-satisfaction in being the one who causes things to be done, and done correctly. This fact alone should encourage you to seek advancement in rate at every opportunity. Of course, there are other inducements to seeking advancement—increased pay, increased military responsibilities and privileges, and more important jobs to be handled, to mention a few.

No one can predict with absolute accuracy what phases the Navy will be assigned in any future war. However, it may be presumed that the Navy will enter any future war with aircraft carriers larger and vastly more efficient and effective than those employed in the last war. Both the aircraft and underwater craft will be greatly improved as to range, firepower, types of propulsion, and speed. Guided missiles of fantastic destructive capabilities and speeds will no doubt be the order of the day. Many other weapons, as yet unknown, will probably help defend our shores and strike back at the enemy. Technological advances in equipment, even now in test phases, will insure a greater and more powerful Navy in all of its many elements.

All of this means that the Aviation Ordnanceman will become responsible for more and more complicated equipment in his everyday work, both ashore and afloat. New weapons and the tactics that make them effective will complicate the job of rearming. For this reason, greater skill and dexterity will be required of the arming crews to ready them for combat, and a closer supervision by you in order for this equipment to perform its necessary tasks. You will have the final responsibility in seeing to it that the aircraft are readied for combat on any type of mission assigned. You will be working with more and deadlier guns, different launchers for rockets and other new missiles, and greatly more complex equipment for automatic pilotage, sighting, and turret control. Undoubtedly, you will be called on to learn how to handle different types of nuclear weapons so that you will be able to pass this information on to those under you, and to effectively supervise their work.

There are many technical experts with training in many fields of service who will maintain the combat aircraft, but in the final analysis it is the Aviation Ordnanceman's duty to add the striking force to the armed combat aircraft. You should look upon your job as one of the most important in a long line of important jobs which, upon successful completion, creates an efficient and hard fighting naval air force.

One of your major duties as a first class or chief petty officer is that of training and supervising those under you. For this reason, it is essential for you to have a thorough knowledge of the techniques of training and supervision. As a leading ordnanceman, you will be called more and more to teach, demonstrate, instruct, lend guidance, and administer to those under you. This means that you will be doing less of the physical job of ordnance maintenance and repair, and more of the necessary instructional detail work. You will have to closely supervise the work of your subordinates at times in order to insure that their work is properly accomplished.

There are many sources of information which will help you in becoming a more proficient supervisor and instructor. A few of these sources are listed here:

General Training Course for Petty Officers, NavPers 10055
Instructor Training, NavPers 92050
Education and Training, NavPers 10827–A
Shipboard Training Manual, NavPers 90110
Manual for Navy Instructors, NavPers 16103–B
Basic Military Requirements, NavPers 10054
Military Requirements for Petty Officers 3 & 2, NavPers 10056

BILLETS YOU MAY EXPECT

There are many billets in the aviation ordnance field to be filled by the first class and chief petty officer. You may wind up in any one of these depending on the circumstances. Knowing this, you will realize the importance of formal schooling in ordnance and the vast amount of personal experience necessary to be eligible to fit into the ordnance work at any one of a number of places. The various billets to which you may be assigned are discussed in the following paragraphs.

Air Department Duty

An Aviation Ordnanceman First Class or Chief in the ship's company aboard an aircraft carrier will normally be assigned to the air department. Here his duties may include being in charge of the aviation magazines; supervision of ammunition breakout crews and working parties; complete charge of ammunition belting equipment; control of fuze lockers and torpedo/mine stowage spaces; and supervision over target equipment and boresighting gear. In addition you may have to check on the coordination of schedules with the air group aboard; maintain certain records and filing systems for equipment; secure publications to cover the ammunition and all equipment to be used by the air group; publish and practice all safety precautions; cause periodic checks to be made on all special protective and emergency clothing and gear; and insure that adequate watches are posted on all assigned spaces and magazines.

Air Group and Squadron Duty

The first class or chief petty officer assigned to a carrier air group functions on a squadron level regardless of whether or not his group is aboard or ashore. Therefore, squadron and air group duties will be considered together. Here, as well as elsewhere, you will be directly concerned with training the men under you. Also, you will find that the squadron pilots will seek your advice on many aspects of the ordnance gear they are to use. Training is a definite part of your work now, and will occupy a lot of your time.

Other duties will include making up work crews; keeping a close check (inventory) on all tools; compiling aircraft availability for operations; causing inspections to be made of all aircraft for ordnance and armament readiness; assigning cleaning spaces and details; maintaining spare parts inventories as shown by allowance lists; having detailed information of gunnery range availability and assignments to your own activity; carrying out small arms drills as prescribed; and insuring that all boresighting equipment and templets are ready for use and in good condition.

If your duty assignment is within a patrol aircraft squadron, you will be called on to rearm waterborne aircraft from rearming boats, which offers certain difficulties over and above those found in accomplishing the same work for landplane squadrons. You will also find that corrosion is one of the major problems in the waterborne patrol squadron. Moisture affects almost every item of ordnance gear. This means that you will have to effectively combat corrosion caused by salt and moisture on turrets, bomb racks, shackles, ammunition, and all other ferrous metal devices. Also, pyrotechnics will have to be safeguarded to prevent their becoming useless due to moisture.

Other details of your duty, along more or less administrative lines, will be to post and carry out all special and general safety precautions; keep a running log on all training allowances and expenditures; maintain work and material requisition logs; make daily assignments of work to crews and individuals; compile the annual ammunition report; keep posted on availability of munition stores assigned to station or ship; keep a complete record of ordnance and armament changes incorporated and reports made; instigate FUR's (Failure or Unsatisfactory Report, NavAer 3069), EFR's (Electrical Failure Report, Form DD 787), and RUMAOE's (Report of Unsatisfactory Mechanical Aviation Ordnance Equipment, NavOrd Form 2458); see that pertinent BuAer publications are up to date and available to the crews; insure that eligible personnel are assigned to schools when practicable; and keep full record of ammunition expenditures and individual gunnery scores. You will find that, in addition to all the above items, you will constantly have to strive to coordinate the activities of your ordnance unit with those of the other units of the air group or squadron, and to instill in your men the will to work and learn as a group.

FASRon Duty

A lot of the work performed in a FASRon is accomplished on a more or less priority basis. There may be periods of time in which there is no more than the routine upkeep and maintenance work going on. At other times the unit will be overloaded with work of a priority nature. This means that you should employ the slack time that may exist to organize for rush periods. Train the men under you so that they will know exactly what to do and how to do it without the necessity of your constant supervision. You will have to plan your work as nearly as possible to fit the anticipated workloads. You will have to order bureau aircraft changes for the aircraft assigned by their respective bureau numbers, and know how to incorporate them most proficiently; insure that the munitions in the magazines assigned to the various squadrons are stowed in accordance with current BuOrd regulations; secure additional help from the squadrons when the FASRon is overloaded; be responsible for sufficient belted ammunition and all linking and delinking equipment; maintain a perpetual inventory of spare parts for aircraft, armament, and ordnance gear; maintain rearming boats and tenders as required and prescribed; make sure that a complete source of technical information is in the files and instantly available for use in daily repairs, maintenance, and overhaul. Here, as elsewhere in the Navy safety cannot be overlooked. This means that you will have to be constantly alert for both hidden and evident dangers in your working spaces and for dangerous working habits and practices of the personnel under you.

Armory Duty

Here you will have charge of records, safety, landing party equipment, surveying of equipment, internal integrity of the unit, assignment and custody of items, and other phases of importance and responsibility.

Magazine Duty

Duty at a magazine involves posting and carrying out strictest safety regulations; keeping a constant vigil for fire hazards; total security for the entire area; interpretation of the magazine instructions on stowage of ammunition; organization and control of various working parties; keeping, or having kept, various records of issues and munitions ordered, including ASRS records; directing and overseeing disposition of unserviceable ammunition and pyrotechnics; recording and reporting daily magazine temperatures; running checks periodically on munitions handling equipment; maintaining a running inventory of all articles normally placed in the magazines; and performing inspections, examinations, and tests on munitions in accordance with current regulations.

Gunnery Range Duty

You may be assigned to duty at a rifle or gunnery range. You may be in full charge of the unit. Your duties here will be to carry out all safety precautions prescribed by higher authority and those you may feel are needed in addition. You will have a never-ending job in this connection, as safety is paramount in a unit of this type. The range itself will have to be kept in perfect order, the targets properly maintained, and the instructors kept at a high level of training through your continued instruction. The paperwork will consist of records of firing; preparation and maintenance of firing schedules; records of receipts and expenditures of ammunition; and records necessary to authorize individual qualifications to be entered into service records and jackets.

Schools and Instructor Duty

You will be sent to an ordnance school either in the capacity of a student or as an instructor during your career as an Aviation Ordnanceman. Your duties while in attendance to or instructing in such a school will be prescribed by the school itself. Your military obligations will be relaxed very little, if any, while on duty at any one of these schools. As an instructor, you may be called on to teach any of several subjects in the field of aviation ordnance. As a student, you will receive training in one or more specialized technical areas.

Special Details

There are numerous special details to which a first class or chief petty officer can and may be assigned. In fact, there are so many different ones that no attempt will be made to list them all here. A partial listing of these duties shows that you may serve in such diverse capacities as being a member of a bomb disposal team; in charge of unloading munitions from barge or rail facilities; assigned to duty at one of the large fleet gunnery ranges; assigned to ammunition depots for various duties; serving on master-at-arms forces; serving on recruiting duty, and possibly duty aboard an aircraft tender where the personnel under you may be fewer in number than elsewhere, but where the duty will be just as significant in its overall aspects.

Although the professional qualifications under which you work at different activities will vary with the type of work being accomplished there, your military requirements will roughly be the same. However, you will be responsible for being able to perform all of the qualifying provisions of your rate with regard to advancement.

QUALIFICATIONS FOR ADVANCEMENT

The fact that you are spending much of your time in the supervision and instruction of the rates under you does not mean that you can afford to overlook the importance of the advancement of your own knowledge and skill in your chosen field of work. Just the opposite is true. You actually have to double your efforts as your responsibilities increase with your advancement in rating.

The qualifications needed for your advancement in rating indicate that you should have wide practical experience and intensive training. You will see what is meant by this statement as you read your requirements for qualifications below. They are:

1. Service and make necessary repairs to aircraft turrets.

2. Maintain and service ammunition linking and delinking equipment.

3. Train and supervise personnel in maintenance and repair of aircraft ordnance and armament gear, including turrets.

4. Train and supervise personnel to properly handle aviation munitions and pyrotechnics.

5. Organize and administer facilities for maintenance and repair of aviation ordnance and armament gear.

6. Prepare reports required by your activity.

7. Supervise use, filing, and maintenance of publications, logs, and records.

8. Determine allowances for materials.

9. Supervise inventory, and account for allowed materials as authorized.

10. Organize and instruct in small arms firing practices and know the regulations for conducting same.

11. Know the operating principles and functions of aircraft bomb directors.

12. Know the procedure for and sources of information concerning the making of boresight charts and templets.

13. Know the practical applications of internal and external ballistics to aviation ordnance in general.

14. Know the uses of all applicable allowance lists, BuOrd publications (OP's, etc.), catalogs, and forms used in requisitioning, salvage, and survey of aviation ordnance materials.

We have already spoken of the increasing complexity of modern aviation ordnance. Matching this increased complexity of the gear itself is an almost equal rise in the complexity of the tools needed for maintenance and repair of this equipment. Electronic meters and testing equipment of all kinds; complicated hydraulic testing gear; tools for specialized adjusting, assembly, disassembly, repair, and maintenance; and a host of other complex instruments are all part of the present-day maintenance equipment. In order for you to properly supervise the maintenance and repairs to modern ordnance and armament gear, you will have to know in detail how to use the testing and repair equipment. This is only natural since you are obligated to instruct those under you in the proper use of this gear. You will also have to KNOW the equipment with which you are working. Otherwise you will not know just how much modification you may perform on the gear without running the risk of ruining it and turning it into useless junk to be surveyed.

In order for you to understand the aviation ordnance and armament equipment currently used, and that to come, requires constant study. You should carefully check all instructional material of the gear for which you are responsible. If there are portions which you do not understand in this or any other phase of your work, it is your responsibility to seek out this information. By doing this you will have all the answers for successful instruction of the men under your supervision. A good teacher never stops learning. Your act of seeking out the right answers affords you most of the knowledge for your own advancement. Skill will then result from personal acquaintance with the equipment.

Reference Publications

No book or set of books will give the Aviation Ordnanceman ALL he needs to know about his job. The element of PRACTICAL EXPERIENCE supplements the knowledge gained through reading of books and publications. Only when practical experience has been gained and wide reading of pertinent materials has been conducted do we have a well-rounded individual. From the above, it is evident that reading cannot be overlooked. This course, while offering only the basic elements of aviation ordnance, still organizes your thinking and learning processes as you study its contents. Other publications will do likewise. They all serve to broaden your knowledge and keep you abreast of the times in other than purely practical aspects of your work.

It would be difficult to find adequate file space in any activity for all of the publications pertinent to the field of aviation ordnance. Likewise, there would hardly be justification for any one activity to order all publications, as there would be little or no use for some of them in the particular activity. Selective ordering is the key. Do not hesitate to order publications needed because they are classified. Proper storage and handling are not troublesome if you have adequately prepared storage facilities and set up approved classified material handling procedures as contained in *United States Navy Security Manual for Classified Matter,* OPNav Instruction 5510.1A. The men under you may be studying for advancement and need publications dealing with gear that is not used in your activity. Any help you can give them by having publications on hand, both classified and unclassified, dealing with the gear they are studying will certainly aid their chances for advancement.

There is a great deal of valuable information for you in the *Bureau of Ordnance Manual* and *Bureau of Aeronautics Instructions.* These two references delineate the overall organization, duties, logistics, supply, joint coordination, regulations, functions, duties, and responsibilities, of the two bureaus with regard to aviation ordnance and armament.

You will find that most of the publications and materials needed to refresh your memory on items and procedures in aviation ordnance have already been obtained by your commanding officer. Each activity has procured these publications automatically from the Standard Navy Distribution List, or under a commissioning allowance by requisition of those publications not forwarded automatically. The *Index of Ordnance Publications,* OP 0, lists the publications of the Bureau of Ordnance. The *Naval Aeronautic Publications Index,* NavAer 00–500, lists all of the BuAer and some of the

BuOrd publications. Those publications not found in your activity may be ordered from these two sources.

The Bureau of Ordnance originates many publications of interest and information to the Aviation Ordnanceman. The major ones are:

Ordnance Pamphlets
Ordnance Data
NavOrd Notices
NavOrd Instructions
Registered Ordnance Pamphlets (RPS–6)
Ordnance Standards (NavOrd OSTD 0)
Bulletin of Ordnance Information
Bureau of Ordnance Armament Summary
Ordnance Specifications
Ordnance Allowance Lists
Ordnance Reports
Bureau of Ordnance Drawings
Bureau of Ordnance Sketches
Ordnance Alterations (NavOrd ORDALT 00)

The SECTIONS of the *Naval Aeronautic Publications Index* which contain listings of vital interest to Aviation Ordnancemen are:

Armament (Aircraft Armament Changes, Aircraft Armament Bulletins, etc.)
Aircraft (Aircraft Manuals, Flight Handbooks, etc.)
BuOrd Publications
BuAer Publications
Training Literature
Aviation Supply Catalog Index

The *Manual of Qualifications for Advancement in Rating,* NavPers 18068, is of vital interest to the Division Officer and the enlisted man alike. Unfortunately, enough is not known about this publication by either the enlisted man or Division Officer in all too frequent instances. This publication is the official manual which promulgates the minimum qualifications for the advancement in rating of enlisted personnel in the Navy and Naval Reserve and shall be used as a guide by all naval personnel concerned with the training and advancement of naval enlisted personnel in accordance with Bureau of Naval Personnel directives. It covers in more or less broad terms the requirements for advancement for all ratings in the Navy, both military and professional. Qualifications for emergency service ratings as well as those for general service ratings are detailed in the Manual.

The Bureau of Naval Personnel issues Changes to the Manual in order to keep the requirements of your rating up to date. The qualifications printed in appendix III of this course, which cover the Aviation Ordnanceman rating, are current only through Change 8. It is, therefore, necessary that reference to the LATEST CHANGE TO THE MANUAL BE MADE IN PREPARING FOR ANY EXAMINATION. Consult your Information and Education office or your Education and Training Officer for the latest changes to the Manual.

A bibliography titled *Training Courses and Publications for General Service Ratings,* NavPers 10052, is issued in revised form annually by the Bureau of Naval Personnel. This booklet lists Navy Training Courses and other publications required or recommended for study for the advancement in each of the rates and ratings. This booklet is also applicable to Naval Reservists on inactive duty. It is a bibliography of reference sources from which examination questions for your advancement will be taken. Training courses which are marked by an asterisk must be completed for specific rate levels before you are eligible to take the advancement examination. It must be realized that, as indicated in the *Manual of Qualifications for Advancement in Rating,* NavPers 18068, all higher pay grades listed in this booklet may be held responsible for the materials in publications listed for the lower rates of that particular rating.

Since in many instances only pertinent sections of publications are listed in the *Training Courses and Pub-*

lications for General Service Ratings, the most intelligent use will be made of this booklet by concurrent reference to the *Manual of Qualifications for Advancement in Rating* for the rating concerned. Here again, it must be assured that the latest Change to the Manual is being utilized.

The Manual and the bibliography are two publications that can be of much service to you in preparing for your advancement. They are available and you should obtain them from your Information and Education office or Education Officer and become familiar with the sections that apply to your rating.

The *Record of Practical Factors,* NavPers 760 (AO) (New 5–56) form, which is a part of your service record, lists the practical factor (military and professional) requirements for the AVIATION ORDNANCE rating. There is a like form for all other general service ratings. As you demonstrate proficiency in each practical factor listed on this form, an entry is made showing the date and the initials of the supervising officer. Any major changes to the *Manual of Qualifications for Advancement in Rating,* NavPers 18068, require that the *Record of Practical Factors* form be reprinted. However, minor changes to the Manual may be recorded in spaces provided on the Record Form. The relationship between the *Manual of Qualifications for Advancement in Rating* and *Record of Practical Factors* is immediately apparent since the practical factor requirements printed in the Record form are taken directly from the Manual. The Record form affords an orderly and meaningful method of recording your progress in advancement towards the next higher rate within the rating.

There are some other publications from which you will obtain a wealth of information which will serve to bolster your background knowledge in general. These publications are:

Naval Ordnance Establishment, NavPers 10825
Naval Airborne Ordnance, NavPers 10826

Human Behavior and Leadership, NavPers 10058
Aviation Ordnanceman 3 & 2, Vol. 1, NavPers 10345
Aviation Ordnanceman 3 & 2, Vol. 2, NavPers 10346
Basic Hydraulics, NavPers 16193
General Training Course for Petty Officers, NavPers 10055
Training Courses & Publications for General Service Ratings, NavPers 10052
United States Navy Safety Precautions, OpNav 34P1
Basic Electricity, NavPers 10086
Basic Hand Tool Skills, NavPers 10085
Blueprint Reading & Sketching, NavPers 10077–A
Mathematics, Vol. 1, NavPers 10069–A
Mathematics, Vol. 2, NavPers 10070–A

With most of these publications at your disposal, or obtainable by ordering, there is ample opportunity for you to become familiar with practically the entire scope of aviation ordnance. However, you will have to procure them and read them constantly if you are to keep properly posted as they represent a lot of written material. It is realized that your life as an Aviation Ordnanceman is a busy one, but it is necessary for you to keep as up to date as humanly possible if you are to be of maximum service to the men under you and to the Navy.

QUIZ

1. Of the many Navy bureaus, the two most closely associated with the field of aviation ordnance are the Bureau of Ordnance and the Bureau of
   a. Personnel
   b. Aeronautics
   c. Yards and Docks
   d. Ships

2. The operation and maintenance of all aeronautical shore facilities are the direct responsibility of the
   a. Bureau of Yards and Docks
   b. Bureau of Aeronautics
   c. Chief of Naval Operations
   d. Bureau of Ordnance

3. The division within the Bureau of Ordnance that has cognizance over installation, maintenance, overhaul, and repair of aviation ordnance equipment is
   a. Planning and Progress
   b. Research and Development
   c. Design and Engineering
   d. Material

4. Aviation ordnance equipment comes under the cognizance of the
   a. Bureau of Ordnance and Bureau of Aeronautics
   b. Bureau of Aeronautics
   c. Bureau of Ordnance
   d. Deputy Chief of Naval Operations (Air)

5. Aviation armament equipment is under the cognizance of the
   a. Bureau of Aeronautics
   b. Bureau of Ordnance
   c. Bureau of Aeronautics and Bureau of Ordnance
   d. Chief of Naval Operations

6. After becoming first class or chief petty officer, you will be called on for
   a. more work of a general nature
   b. less general work, but more specialized work
   c. more work in the capacity of instructor
   d. more of the actual physical work

7. As an Aviation Ordnanceman, you will be concerned more with the offices of BuAer entitled Assistant Chief for Design and Engineering, Assistant Chief for Materials and Services, and the
   a. Chief of the Bureau of Aeronautics
   b. Assistant Chief for Research and Development
   c. Deputy Chief of Naval Operations (Air)
   d. Chief of the Bureau of Ordnance

8. The development of the guided missiles comes under control of the
   a. BuAer and BuOrd jointly
   b. Assistant Chief for Design and Engineering
   c. Assistant Chief for Research and Development
   d. Deputy Chief of the Bureau of Ordnance

9. The responsibility for and cognizance of ordnance equipment is sometimes shifted between the Chief of the Bureau of Aeronautics and the
   a. Deputy Chief of Naval Operations (Air)
   b. Aviation Ordnance Branch
   c. Chief of the Bureau of Ordnance
   d. Assistant Chief for Design and Engineering

10. Bomb cranes, cargo trucks, and bomb trailers fall under the cognizance of the Bureau of
    a. Aeronautics
    b. Yards and Docks
    c. Supplies and Accounts
    d. Ordnance

11. The qualifications for advancement for first class and chief petty officers include
    a. use, filing, and maintenance of publications, logs, and record
    b. preparing reports required by own activity
    c. salvage and survey of aviation ordnance materials
    d. all of the above

12. In order to supervise the maintenance and repair of modern ordnance and armament equipment, you will have to
    a. know all of the steps by heart
    b. know how to use the testing and repair equipment correctly
    c. have attended the AT(B) School (Aviation Electronics Technician School, Class B)
    d. none of the above

13. The source which lists all pertinent ordnance publications is the
    a. *Ordnance Pamphlet*
    b. *Ordnance Data*
    c. *Bulletin of Ordnance Information*
    d. *Index of Ordnance Publications* (OP 0)

14. Sections of the *Naval Aeronautic Publications Index* of interest to the Aviation Ordnanceman are
    a. Aviation Supply Catalog Index
    b. Training Literature
    c. Aircraft
    d. all of the above

15. The Bureau of Ordnance normally has cognizance over
    a. turrets
    b. bombs
    c. bomb shackles
    d. aircraft armor

16. The publication which sets forth in broad terms the minimum qualifications for advancement in rating of naval personnel is the
    a. *Bureau of Ordnance Manual*
    b. *Manual of Qualifications for Advancement in Rating*, NavPers 18068
    c. *The Record of Practical Factors*, NavPers 760
    d. *Bureau of Aeronautics Manual*

17. The publication which lists all of the Navy Training Courses and other publications recommended and/or mandatory for study for advancement in each of the rates and ratings is the
    a. *Training Courses and Publications for General Service Ratings*, NavPers 10052
    b. *Manual of Qualifications for Advancement in Rating*, NavPers 18068
    c. *List of Training Publications*, NavPers 10061–D
    d. *Naval Aeronautic Publications Index*, NavAer 00–500

18. When using the *Manual of Qualifications for Advancement in Rating* as an aid to forthcoming examinations, you should establish for sure that
    a. there are eight rating groups contained therein
    b. Changes have been made to the Manual
    c. the letter of promulgation is contained therein
    d. the latest Change issued by the Bureau has been incorporated

CHAPTER 2

AVIATION BALLISTICS

The term BALLISTICS is the name given to the science of the motion of projectiles and missiles. It is the study of all the various forces, both controllable and uncontrollable, which govern their movements.

The study of ballistics is normally divided into two branches. These branches are called INTERIOR and EXTERIOR BALLISTICS. The study of interior ballistics is primarily concerned with the movement of projectiles inside the bore or barrel of the gun. There are a great many highly technical subjects to be considered in the study of interior ballistics. For this reason, and due to the fact that the Aviation Ordnanceman is not strictly accountable for an academic knowledge of interior ballistics, detailed coverage of this branch will not be attempted in this course. However, in order to have at least an insight into the problems of interior ballistics, certain phases will be discussed here. In the study of interior ballistics it is necessary to deal with the mechanical, ballistic, and service conditions of the gun itself; type and characteristics of the powder charge, or grain; ignition and inflammation; combustion and products of combustion; chamber pressures; projectile velocities; internal gun temperatures; heat cracks; adiabatic expansion; erosion of the barrel or bore; life of the gun; and many other complicated and involved factors of this exacting study.

The actual science of ballistics is so highly involved that even today the ballistics scientists, or ballisticians, are still trying to solve many of the problems that have been in evidence since the time the Romans started throwing rocks and boiling oil at their enemies with their "ballista." Since the gun manufacturer, the powder maker, the ballistician, and the services who buy or manufacture their own guns are those primarily concerned with the interior ballistics of guns, the Aviation Ordnanceman need not become involved to any extent. His interests and responsibilities lie in the practical application of aviation ballistics as it applies to the equipment with which he works.

The study of exterior ballistics is concerned with the projectile, the bomb, and the rocket **AFTER** they are fired or leave the aircraft; or the free flight phase of the projectile. The science of exterior ballistics has for centuries engaged the minds of some of the world's best mathematical geniuses. The English are credited with creating the problems associated with interior ballistics when they began gun-launching projectiles at the French in the year 1346. However, it was not until 1537 that Nicholas Tartaglia wrote and published a paper on the flight of a projectile. This was probably the first of many such works which followed on the same subject. Galileo made investigations into the trajectories within a vacuum. Even Newton delved into the effects of air resistance on trajectory. In the year 1753, Euler gave us the approximate mathematical solution of trajectory in air. This fact is of particular interest in that the solutions of these problems, which were worked out around the middle of the eighteenth century, have only recently been adopted for our own use in making calculations in trajectory.

In considering the study of ballistics, there are four major factors with which to deal. These are the **PROPELLING FORCE**, **GRAVITY**, **AIR RESISTANCE**, and the **ROTATION OF THE PROJECTILE**. (See fig. 2–1.) However, ballistics from the standpoint of aviation necessitates the addition of another important factor: the **FORWARD MOTION OF THE AIRCRAFT**. These factors will be discussed later.

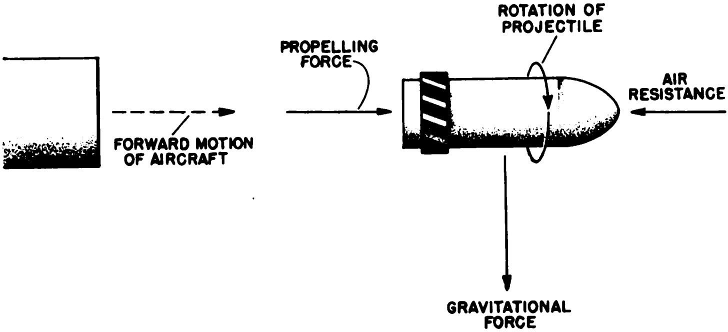


Figure 2–1.—The ballistic forces.

INTERIOR BALLISTICS

The mechanical condition of the gun has to be such that it will withstand the stresses set up by the violent and very rapid combustion of the propelling charge. After the stresses involved have been determined through the science of interior ballistics, the construction of the weapon is then governed by a factor in the computations called the ELASTIC STRENGTH OF THE WEAPON. Elastic strength formulas are used to compute the points that compose the strength curve of the gun. The gun must be designed to produce a given ballistic result in delivering a specified weight projectile at a given muzzle velocity with the minimum possible stress on the gun. Finally, the gun must meet the service specifications with regard to ease of breech and loading operations.

EXPLOSIVES.—There are two broad classifications of explosives, HIGH EXPLOSIVES and PROGRESSIVE EXPLOSIVES. The high explosive, often referred to as an explosive of the FIRST ORDER, is used primarily as a charge in bombs, explosive projectiles, mines, torpedoes, grenades, and the like. The progressive explosive, which is called an explosive of the SECOND ORDER, is used primarily in rockets, JATO, and in all types of guns and rifles as a propellant. The progressive explosive used for some years now is SMOKELESS POWDER. It is manufactured in a great many sizes and shapes of grain in order to best adapt it to the various uses to which it is put. Smokeless powder is a chemical mixture whose components are combined by synthetic chemical reaction into a molecular compound. It is relatively hard to ignite. For this reason a primer charger is used to set off an ignition charge which, in itself, is sufficiently powerful to detonate the smokeless powder charge.

IGNITION.—Spreading of the flame during ignition of the powder grain, or grains, is known as INFLAMMATION. This process differs radically in various powders due to their compositions and the amount of surface areas exposed to the progress of ignition. Most nations have used smokeless powder since about 1880. Despite the fact that this powder is harder to ignite than others, it has numerous advantages over the older types of powders. The burning rate of this more powerful powder (propellant) greatly exceeds that of the older types. During combustion it is transformed almost entirely into gases and water vapor with relatively little smoke and no solid residue. Each charge of smokeless powder has associated with it a small igniter charge of black powder. Ignition of this small charge by the primer charge is sufficient to produce, within the air spaces surrounding the charge of smokeless powder, an instantaneous flame of such volume that ignition of all portions of the main charge will occur at the same instant. The ignition charge also furnishes an initial pressure within the chamber which is necessary to insure rapid and complete ignition.

Experiments have shown that smokeless powder burns in parallel layers of molecules in directions perpendicular to all ignited surfaces of the grain, and at a uniform rate of velocity. (See fig. 2–2.) As each layer of molecules burns, the next layer of molecules is exposed to combustion. This process continues until the grain is consumed. Burning under pressure increases the velocity of combustion. However, pressure does not affect

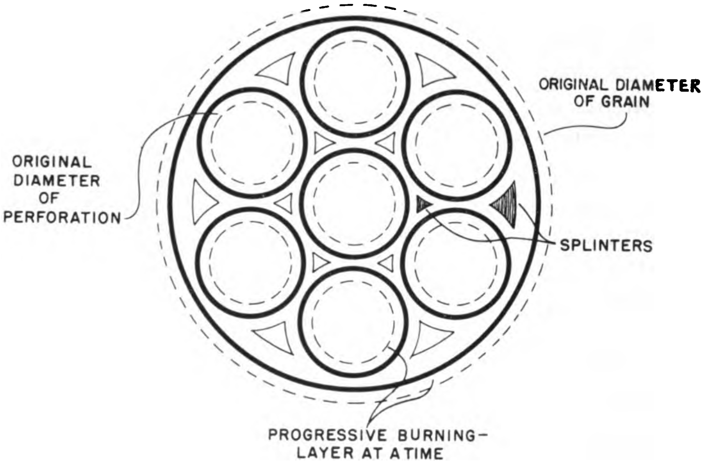

ORIGINAL DIAMETER OF GRAIN
ORIGINAL DIAMETER OF PERFORATION
SPLINTERS
PROGRESSIVE BURNING—LAYER AT A TIME

Figure 2–2.—Flame propagation (inflammation) in smokeless powder. End view of a multiperforated grain.

the manner in which the powder burns—that of burning in successive layers of molecules from outside to inside.

When smokeless powder burns, practically all of the materials forming its composition are converted into carbon dioxide, carbon monoxide, nitrogen, hydrogen, water vapor (steam), and oxides of nitrogen. Smokeless powders are either DOUBLE BASE or SINGLE BASE compounds. The double base powders are made from NITROGLYCERIN and NITROCELLULOSE. The nitroglycerin is used as a solvent in forming the grains of this compound. The single base powders are made from nitrocellulose. The grains of this powder are made by using ETHYL ETHER and/or ETHYL ALCOHOL as solvents with which to form the grains. The same gaseous products of combustion are formed by both the single and double base powders. However, the proportion of the various products of combustion formed by these two powders vary considerably. Nitroglycerin contains a greater percentage of oxygen than does nitrocellulose. For this reason a greater amount of carbon dioxide is produced by the nitroglycerin during combustion than by nitrocellulose.

COMBUSTION.—Combustion of a grain of smokeless powder takes place entirely on its surface. Since this is true, the amount of surface exposed to inflammation of the grain determines the rate, or velocity, of burning. Various types and shapes of powder grains present varying amounts of surface to combustion. Therefore, by varying the amount of surface area per unit volume, and by varying the ingredients of the powder, great differences in combustion speeds may be obtained.

To maintain original conditions of effectiveness within smokeless powders during long periods of storage, the Navy adds to this powder a basic compound of DIPHENYLAMINE. This chemical additive has an affinity for, and therefore absorbs, NITROUS VAPORS readily. Nitrous vapors are the first products evidenced in a decomposing powder. If they are not absorbed from the very beginning of this decomposition, they will be generated at a constantly increasing rate as the powder decomposes, and will build up a positive pressure inside the container. With the addition of diphenylamine to the powder, decomposition is practically eliminated. Decomposition will not occur in the powder until all of the diphenylamine has been exhausted through absorbing the nitrous vapors. As a result of combining this additive with the powder, the useful life of smokeless powder has been increased from 6 to 8 years to roughly 15 to 20 years while in storage.

It has been found that when the double base smokeless powders are used in extremely cold climates, an added hazard arises in its use. If, due to extremely cold conditions, this powder is frozen, the nitroglycerin reacts as a high explosive when ignited. Should this occur, the gun would undoubtedly rupture when fired.

PROPELLANTS AND CHARGES.—In any weapon, the charge or propellant is designed to give a desired result, or effect. In the bomb, mine, torpedo, and weapons of this type, the charge is compounded from elements in such a manner that it will EXPLODE INSTANTANEOUSLY.

In so doing, it produces a first order explosion which gives a high explosive effect. The desired result of violent rupture of the case with attendant powerful blast effect is obtained. The type of propellant used in all guns, rockets, JATO, etc. is entirely different in its characteristics. It is a progressive or second order explosive designed TO BURN AND NOT EXPLODE. The effect of this type of powder is to give a tremendous propelling force to the projectile or missile by burning very rapidly a powder that produces heat and gases in ever increasing volume until consumed. Great propulsive forces are thereby generated which drive the projectile through the air, and, in the case of the rocket, are emitted through a venturi arrangement at the rear of the rocket motor to produce a reaction with the surrounding air in creating thrust.

The velocity at which powder burns has been worked out very accurately for various powders under varying conditions. A STANDARD INITIAL VELOCITY has been calculated for all guns, and the desired optimum powder temperature of 90° F. was used as a standard for these tests. It has been assumed that a variation of one degree (plus or minus) from this standard temperature causes a variation of two feet-seconds (plus or minus) in the initial velocity of all guns. This is an approximation, but will serve as an average for all guns and all likely temperature variations. Variations in excess of 20° F. should be strictly avoided for safety by control of the temperatures in the magazines.

A definite residual moisture and volatile content is specified for each powder composition and granulation. Powder may also contain small percentages of some stabilizer (such as diphenylamine mentioned earlier), graphite, and inert materials. All of these materials and ingredients affect the energy of the powder, and any of these changes will cause ballistic variations. The only variations in composition likely to result in service are those involving loss of volatiles and change in moisture content. A one percent change in volatiles will produce a change in the burning rate on the order of ten percent.

PRESSURES AND VELOCITIES.—The potential of a powder is the total work that could be performed by the unit weight of the products of combustion when indefinitely expanded without loss of heat, if all of the heat being used were expended in the performance of work. Naturally, this condition could never exist due to the fact that roughly 59 to 70 percent of the energy (heat) is carried away into the atmosphere as the gun fires and the projectile leaves the bore of the gun. It is highly interesting to note that the potential energy of powder is relatively low when compared with that of most of our everyday fuels. This fact may at first seem ridiculous. However, the rate of delivery of energy of powder is so tremendous that we may have been subconsciously lead to believe that powder has a great deal more "power" than our fuels. Actually, the energy stored in a pound of smokeless powder (nitrocellulose) is about 560 foot-tons per pound, whereas that of our common fuels runs vastly higher; gasoline, for instance, being well over 7,000 foot-tons per pound.

A Frenchman named LeDuc developed the formulas many years ago with which we first carried out our own experiments in velocity and pressure in our guns. After investigation, these formulas were found to be only slightly inaccurate, and by far the simplest and easiest ones with which to determine the factors of velocity and pressure. Although LeDuc's formulas are empirical, they are sufficiently accurate to give approximations of velocities and pressures to be expected when using a powder designed for medium guns.

Our original experimentation was conducted by powder expert G. W. Patterson of the Naval Proving Grounds. Measurements of both internal pressures and velocities of projectiles were made by cutting off the barrels of four identical 5-inch guns at different locations along the lengths of the barrels, and firing several service rounds in each of them. Velocity readings were taken by a chronograph and by having the projectiles cut wires in the circuit with the chronograph which were set ahead of the guns at predetermined and accurately measured distances apart. The recording and measuring device (chronograph) was activated as the sets of wires were cut. Pressures were determined through the use of a crusher gage. From the data gathered in this experiment, Mr. Patterson was able to develop the formulas subsequently used for many years in computing velocities and pressures in our guns. As a matter of fact, the powder charge and internal pressures were calculated from the data produced by these tests for the first 16-inch 45-caliber naval gun before it was actually built. These values were found to be very nearly exact upon test firing this new gun after its production.

TEMPERATURES.—Temperatures in the metal of the gun after firing a number of rounds become rather high. If subsequent rounds are allowed to remain in the chamber for any appreciable length of time before firing, the muzzle velocity of those rounds will be greater than previous rounds due to the fact that the temperature of the powder charge has a chance to rise. However, if the subsequent rounds are fired as they enter the gun chamber, there will be no appreciable increase in muzzle velocity as the powder charge temperature will not have had sufficient time to rise. The first round fired from a cold gun may have a muzzle velocity which is less than that normally calculated for that gun. For this reason a COLD GUN CORRECTION is made to compensate for the reduction in muzzle velocity, and consequently range. that accompanies the firing of a cold gun. Normal range tables are computed on the basis that a warming round has been fired through the gun. So it is that a round fired from a cold gun is not apt to give the results shown in these tables. These cold gun corrections can only be determined from careful postfiring analysis, and they may change materially during the life of the gun involved. Also each gun has its own characteristics with respect to range and trajectory when fired cold, or after becoming heated.

As an example of the changes in muzzle velocity with changes in powder temperatures for a large caliber gun, the following figures are reproduced from the firing tables of a 105-mm howitzer whose muzzle velocity is 710 feet per second.

Temperature of powder, degrees F.	*Change in velocity, feet per second*
0	–22
10	–19
20	–16
30	–13
40	–9
50	–6
60	–3
70	0
80	+3
90	+6
100	+9

ADIABATIC EXPANSION.—Powder must be selected to "fit the gun" under consideration. That is, the powder to be used must NOT burn so rapidly that complete combustion will occur before the projectile is started down the bore. Were this to happen, dangerous chamber pressures would build up causing violent rupture of the gun barrel or breech mechanism. On the other hand, the powder should have completely burned before the projectile actually left the muzzle of the gun, in order that the greatest possible amount of energy be derived from the powder. ADIABATIC EXPANSION (where gases expand and perform work in a space which is impermeable to heat) is a factor in the determination of the optimum pressures within the gun during the combustion of the powder charge. In other words, the gases NEITHER RECEIVE NOR LOSE HEAT FROM OR TO THE CONTAINER, ALTHOUGH in performance of work they naturally give up their energy in the form of heat. Thus it is that BOTH the temperature and, since the gases are expanding, the pressure diminish.

HEAT CRACKS.—Heat cracks sometimes develop within the bore of a gun during its service life. These cracks are caused by differential heating of the barrel from the inside towards the outside of the gun, as well as by passage of the projectile through the bore. These cracks are generally not considered serious because their development is not critical within the extent of the accuracy life of the gun. Heat cracks are not considered a technical phase of erosion of the bore. However, they do make it easier for the hot gases moving at high velocities to "wash" away the metal of the bore. (See fig. 2–3.)

EROSION.—Intense heating of a thin layer of metal at the surface of the bore by the gases of combustion causes erosion of the gun bore. Added to this effect is the rush of these same intensely heated gases past the projectile and down the bore surface of the gun. Erosion results in a gradual enlargement of the bore and smooth wearing away of its surfaces. It begins at the rear of the bore near the origin of the rifling and extends further down the bore as the gun is repeatedly fired. The lands of the bore are eroded—roughly twice as fast as the grooves. (See fig. 2–3.)

There are other types of erosion besides that of gas erosion. SCORING of the gun bore takes place where defects or scratches exist in the bore. The hot gases bypassing the projectile at such a location are given an added impetus by a nozzle or vent action and tend to score the metal at this point. Once scoring starts, unlike the basic gas erosion, it increases rapidly with each round although it does not usually become evident until after several rounds have been fired. Scoring usually starts in the upper part of the barrel, most likely due to the fact that the weight of the projectile causes greater clearance at the top when it is seated in the

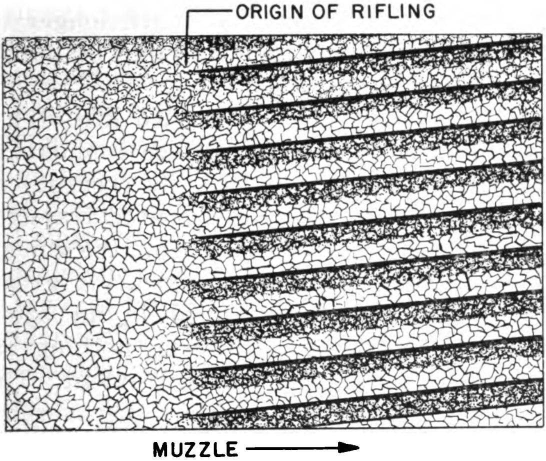


Figure 2—3.—Advanced gas erosion and heat cracking in a 155-mm gun.

bore. The effects of scoring do not usually become serious to the strength of the gun because most guns become too inaccurate for further use before the scoring is sufficiently advanced to give trouble.

ABRASION is another form of erosion. It is a slow mechanical wearing away of the lands after a large number of rounds have been fired. The greater wear of the bore caused by abrasion normally occurs at the bottom of the bore at the origin of the rifling because of the greater friction between the projectile and the bore at the bottom.

The primary effect of erosion is a drop in peak pressure and hence a loss in muzzle velocity. Under actual firing conditions with a worn gun, there is a small range loss not attributable to the loss in velocity. This may be due to the increased yaw about which you will study later in this course, or for other reasons. Since this particular loss is very small, nearly all of the range loss exhibited can be attributed to muzzle velocity loss. In the case of antiaircraft guns, where range has been impaired by erosion, the projectile will have an increased time of flight for the same range. This means that the target fired upon will have that much longer to move before the projectile can reach its point of impact. Inaccuracy results.

SERVICE LIFE OF GUN.—The service life of a gun is determined by the number of service rounds that may be fired through it before it loses its accuracy or sufficient energy is lost to affect the desired trajectory. If erosion did not take place within a gun, the gun's service life would be spectacularly prolonged. A great many experiments have been performed in an attempt to lessen the rate of erosion. However, nothing has been found that will inhibit erosion to any extent. There are naturally other factors which affect the overall life of the gun. A few of these are improper cleaning, faulty preservation, incorrect lubrication for the existing conditions, use of improper cleaning materials, failure to clean, exposure of the weapon to the elements, failure to replace worn parts at the time they need replacing, failure to incorporate authorized changes to the weapon promptly, and failure to maintain proper working clearances at all times. These are mechanical factors in the overall life of the weapon, and should not be confused with the ballistician's definition of the "service life" of the gun as previously defined.

EXTERIOR BALLISTICS

The Aviation Ordnanceman is much more intimately concerned with exterior ballistics in his everyday work than with interior ballistics. It is even necessary for the Aviation Ordnanceman to have a practical knowledge of exterior ballistics in order for him to understand what happens to the projectile, the bomb, the torpedo, the rocket, and other missiles after they have been fired, dropped, or otherwise launched. You have already been told that the field of exterior ballistics is a highly complicated and complex science. To bring this science strictly into the realm of practical application is not an easy task, as there are areas in the field in which theory and emipirical solutions are still employed to justify assumptions. For this reason, as well as others, an academic mathematical approach to the subject of exterior ballistics will not be employed in this course.

TRANSITIONAL BALLISTICS.—It is quite possible that you have gathered the impression thus far that there is a clear-cut demarcation between interior and exterior ballistics. Such is not the case. Actually, during the time the projectile is traveling down the bore of the gun there are several forces and actions produced which do not fall under either of these categories. However, these forces and actions do produce a profound effect on exterior ballistics and cannot be overlooked in seeking an understanding of the subject. This phase we call transitional ballistics.

As the projectile moves down the bore of the gun, the static airmass forward of the projectile in the barrel is forced down the bore and emerges from the muzzle in advance of the projectile. Traveling at a high rate of speed, this airmass strikes the outside air and creates a spherically developed disturbance which produces a shock wave. Into this highly disturbed air rushes a portion of the propellant gases which have forced their way ahead of the projectile which is still in the bore of the gun. Then, as the projectile leaves the muzzle, the main mass of propellant gases pour out into the already turbulent outside airmass. At this instant the propellant gases and the projectile have the same rate of speed. However, as the projectile reaches a point forward of the muzzle, the still expanding gases of the propellant charge suddenly increase their speed and overtake the projectile. These escaping gases reach a speed of approximately twice that of the projectile at this point. This action imparts an additional thrust to the projectile. For this reason, the projectile gains its maximum velocity not directly at the muzzle, but at some short distance AHEAD of the muzzle.

Another factor which may be classified under transitional ballistics is that of vertical jump. In an exaggerated case one may imagine a gun tube long enough to show a measurable "droop" along its axis due to a proportional lack of rigidity of the tube in comparison to its length. When this gun is fired, the tube will tend to flex upward similar to the reaction of a hose nozzle when water is suddenly turned on. The projectile and gases passing at high velocity down the bore of this gun will cause the gun tube to be whipped upward violently. It may be seen from this that at the instant the projectile leaves the muzzle, the tube of the gun will be flexed upward above the normal axis of the bore. This action will cause the projectile to leave the gun at a higher angle of departure than originally intended. Even the familiar 20-mm guns react to a minute degree in this manner.

There are other factors affecting the gun during the interval of transition from interior to exterior ballistics. As the projectile is rotated by the lands of the bore, a reaction (counter force) is set up in the gun to offset this rotational force. This results in a counterclockwise twisting moment in the gun tube if the bore is rifled in a clockwise direction. Another factor is the rapid change in the center of gravity of the gun system as the projectile progresses down the tube. This tends to cause the muzzle of the gun to move towards the ground. The final factor worthy of mention is the stability of the carriage, or gun mount. Any lack of complete stability or rigidity of the gun components will have an effect on the operation of the gun.

The various factors which have been brought out in connection with transitional ballistics, while having a decided effect on exterior ballistics, will not be considered in the study of this phase of ballistics because of the added confusion it would create, and because such a study is not considered essential to the understanding of the basic concepts of exterior ballistics. As a consequence, exterior ballistics will be considered herein with the idea in mind that the projectile, of whatever type, is in free flight.

PHOTOGRAPHY OF PROJECTILES IN FLIGHT.—We have all probably wondered exactly what takes place in the surrounding air when a projectile is fired through it at supersonic speeds. So have the scientists. The study of the flight of projectiles was given a tremendous boost when it was discovered that actual photographs could be taken which showed in detail a portion of the flight of a supersonic missile. Much data has been compiled on the flight characteristics of the projectile, as well as interpretations made of the sound (shock) waves which accompany the supersonic flight of many types of projectiles. It is a fascinating study. Although this study of projectiles in flight is not too closely associated with the information which the Aviation Ordnanceman is required to know, it is highly informative and interesting, and will be briefly considered here.

With suitable lighting and photographic equipment, photography can be made to show clearly the nature of disturbances of the surrounding air caused by a projectile in flight. A well-defined sound or shock wave may be seen to emanate from the point of the projectile traveling at a supersonic rate of speed. (See fig. 2–4 (A).) This visible sound wave is formed by an infinite number of disturbances of the air at the tip of the projectile as it progresses through the air. The radii of these infinite numbers of disturbances are proportional to the intervals of time that have elapsed since the projectile passed through them. A line drawn tangent to the periphery of any one of these receding sound waves will be tangent to all others. Considering an infinitely great number of these successive positions of the projectile throughout its air path, the peripheries of the resulting waves evidently form a straight solid line. These infinite numbers of lines then form a wave front that is visible photographically. A demonstration to prove this receding wave theory was performed by firing a projectile through a tube which had been perforated with evenly spaced transverse slots. These slots allowed a portion of the waves to escape. (See fig. 2–4 (B).) The waves that did emerge produced a wave front by combining after passing through the slots to form a visible wave front as it was assumed they did.

It was also found that the wave front produced by a projectile traveling faster than the speed of sound forms an acute angle aft from its tip, whereas the wave front produced by a projectile traveling slower than sound loses this visible sound wave and forms a visible but detached wave of condensation in advance of the projectile, as shown in figure 2–4 (C).

From theoretical considerations, as well as from indications obtained photographically, it appears that a projectile in flight loses its energy due mainly to three effects:

1. Energy is dissipated in the creation of suction and eddy currents (the marked turbulence to be seen in the wake of the projectiles in fig. 2–4), the amount of dissipation being indicated by their proportions. This effect is evidently influenced mainly by the form of the projectile, especially the form of its afterbody.

2. Energy is dissipated in the creation of air waves. The amount of this effect is evidently influenced by the form of the projectile and by its cross sectional area.

3. Energy is dissipated in the form of heat generated by frictional resistance. This effect is evidently influenced by the form of the projectile, as well as the area and characteristics of its surface.

Although there is not sufficient evidence to permit assignment of percentages to the above effects which cause loss of energy and speed, there are indications that the first two listed effects probably account for most of the total loss of energy suffered by the projectile.

Photography of one type or another has been a tremendous aid in the study of ballistics. Another use to which it has been put is depicting what happens to a

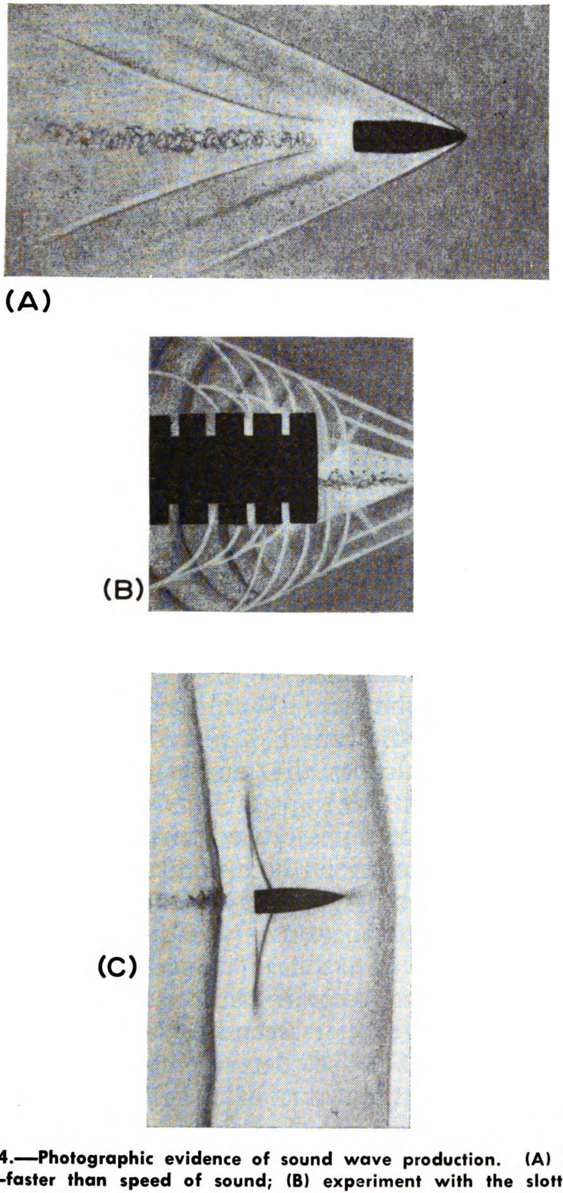


Figure 2—4.—Photographic evidence of sound wave production. (A) Projectile in flight—faster than speed of sound; (B) experiment with the slotted tube; and (C) projectile in flight—slower than speed of sound.

projectile when it explodes, in studying the effects of fragmentation. A series of nine flash radiographs have been taken which record nine different consecutive phases in the static detonation of a 20-mm projectile loaded with tetryl. The exposures for these nine recordings were each about one microsecond (1,000,000th second). They clearly show the size, shape, and number of fragments; the relative sequential period of time in microseconds at which the projectile ruptured sufficiently for the gases to escape through failure cracks; the wide variance in size and shape of fragments; and many other features of great importance to the ballistician.

TRAJECTORIES.—The trajectory of a projectile, be it bullet, bomb, shell, or rocket, is a curve in space traced by the center of gravity of that projectile as it moves through the air. Although the term trajectory is sometimes applied to the path of a projectile through a medium other than air, such as the path of a projectile through water after impact (underwater trajectory), the term is usually restricted to infer the path of the projectile from the muzzle of the gun (or launcher) to the first point of impact. The origin of the trajectory is the position of the center of gravity of the projectile at the instant it leaves the muzzle of the gun or the launcher. (See fig. 2–5.)

The trajectory of a projectile is made to curve by the force of gravity acting on it in flight. There are variations in the values of gravity in different geographical locations. For instance, the value of gravity at the equator at sea level has been determined to be 32.087 feet per second per second. At the poles the value of gravity is 32.257 feet per second per second. The Navy uses a value of 32.16 feet per second per second. This corresponds with the value of gravity at latitudes 41 degrees north and south. This value is used in all computations involving gravity directly. There is also a variation in the value of gravity with increase in altitude. However, for practical purposes this change in

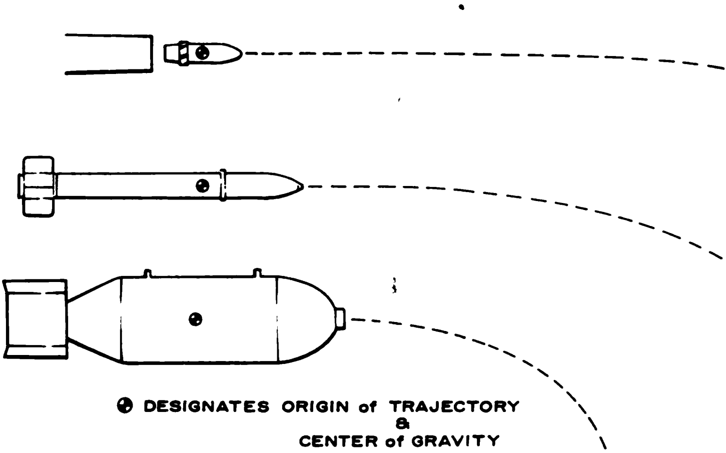


Figure 2–5.—Trajectories of various missiles in air.

value between the surface of the earth and the optimum altitude reached by the projectile is not considered consequential. The reason for this is that these changes are very small in comparison with other factors involved in the trajectory of a projectile. This is especially true with respect to the retardation of the projectile by air resistance.

The factors which influence the curve of the trajectory of a specified projectile after it leaves the gun or launcher are primarily the earth's gravitational field and the characteristics of the air through which the projectile passes. For extremely long range trajectories of the large caliber guns, additional factors must be considered. These are the earth's curvature, the rotation of the earth, and the variation of the earth's gravitational field with altitude. A discussion of these factors will not be undertaken in this course.

One of the major characteristics of the air through which a projectile passes, which has a pronounced effect on trajectory, is the DENSITY OF THE AIR. Very dense air, in which the particles of air are closely packed, offers more resistance to the passage of the projectile than less dense air. It is generally thought that the retardation of a projectile in flight varies directly in proportion to the density of the air. This theory has never been proven experimentally, but is nevertheless commonly accepted by ballisticians. Under an assumption of this nature it is possible to express the ratio between retardations under differing conditions of air density by means of a factor which expresses the ratio between the densities themselves. In other words, a given percentage of variation in air density is assumed to cause a like percentage variation in retardation of the projectile.

ROTATION OF THE PROJECTILE.—Guns are rifled the length of the bore in order to impart a spinning motion or rotation to the projectile. This spinning action stabilizes the projectile in flight. The grooves and lands of the rifling are so constructed as to give a clockwise rotation (in most weapons) to the projectiles as viewed from the rear of the gun. Since a rotational motion is imparted to the projectile as it progresses down the bore, the projectile upon entering free flight becomes a gyroscope in a sense. It attempts to obey all the laws of the gyroscope.

There are certain missiles which are stabilized in flight by fins, and need not be rotated to exhibit stable flight. These missiles have their centers of pressure located BEHIND their centers of gravity due to the large surface areas of the fins located aft. However, the projectile, which is spin-stabilized and has no fins, has its center of pressure FORWARD of the center of gravity. The major problem in creating a stable projectile then becomes a matter of making the center of pressure stay as close to the trajectory as possible. You will remember that the trajectory is traced by the center of gravity of the projectile.

In order to obtain the maximum ballistic results in trajectory and fuze action, the projectile has to rotate at exactly the correct speed. The gyroscopic effect is dependent upon the rate of spin of a projectile. If the projectile is overspun, it will become so stable that it will fail to "nose over" after passing the highest part of its trajectory. In other words, it precesses very slowly due to the extreme speed of its spinning, and thereby becomes so stable that its nose cannot dip far enough to remain on the rapidly dropping trajectory. If the projectile happens to be nose fuzed, it is quite conceivable that it might not explode under the above conditions as the body aft of the ogive and fuze may be the first part of the projectile to strike the target. A projectile which has been spun too slowly, or underspun, tends to precess rapidly. It will have insufficient stability due to the decrease in gyroscopic effect, and will eventually tumble.

DRIFT AND PRECESSION CAUSED BY ROTATION.—A projectile during flight is subjected to a force which causes it to DRIFT. Drift is the lateral deviation of the point of fall from the original plane of fire. (See fig. 2–6.) This deviation, or deflection as it sometimes is called, is entirely due to the effects set up by the rotation of the projectile. There are other causes of lateral deviation, such as wind. However, these deviations should not be confused with pure drift. It is an interesting sidelight that a complete explanation of the drift of a projectile is more dependent upon conjecture to a greater extent than any other phase of ballistics. Even eminent authorities on this subject disagree as to some of the details of the causes of drift. Normally, the three generally accepted causes of drift in an elongated projectile are: (1) gyroscopic action of the rotating projectile; (2) action of the air adhering to the projectile; and, (3) the cushioning effect of the air banking up on one side of the projectile. The two latter causes are generally thought to have only a very minor effect in comparison to the first.

Any rotating body exhibits certain patterns of behavior by virtue of its rotation. One might say that an object acquires new capabilities when spin is imparted to it. An everyday example of this phenomenon is the spinning of a toy top. As a top spins, instead of falling over due to the force of gravity, it attempts to fall out

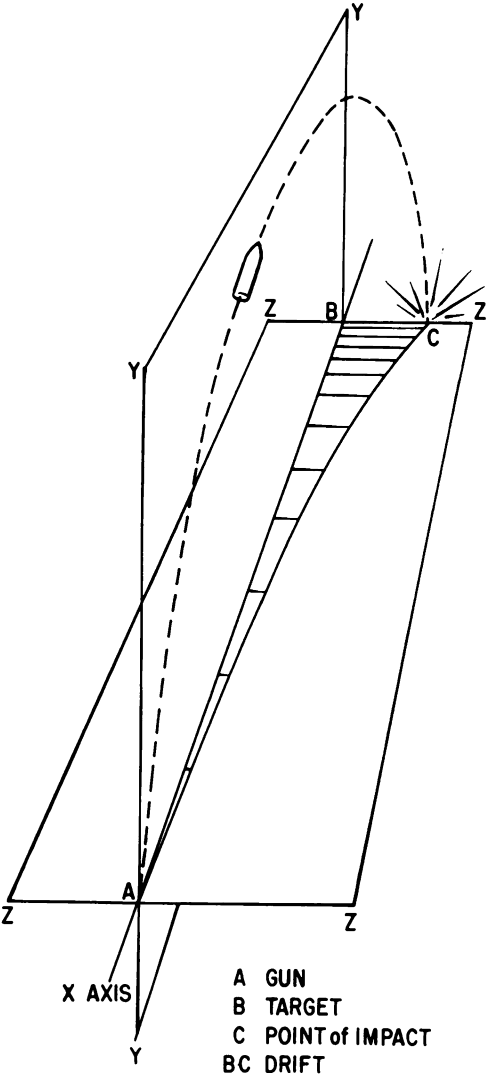


Figure 2–6.—Drift of a projectile in flight. (Lateral deviation.)

of the plane containing the vertical and its own axis. The attempt to fall out results in a rotation of this plane about the vertical as exhibited by the spinning top as it begins to wobble. Any point on the axis then describes a circle about the vertical, and this circling is called PRECESSION Gyroscopic action of the projectile in flight tends to keep the projectile's axis in the direction of the line of departure of the gun. (See fig. 2–7.) However, the center of gravity follows the curved path of the trajectory, and the instantaneous direction of its motion, at any point, is that of the tangent to the trajectory at that point. The projectile's tendency to maintain the original direction of its axis soon results in this axis pointing slightly above the tangent to the trajectory. Air resistance which opposes the flight is then applied to the underside of the projectile. This action is shown in figure 2–7 in which the tangent to the trajectory is tangent at the point occupied by the center of gravity of the projectile.

If the center of pressure *A* were so located as to always lie in line with the center of gravity, this condition would continue to exist. In other words, the axis would maintain its original direction and make an ever increasing angle with the tangent. However, the relation between the weight distribution and surface area of elongated, ogival-headed (shaped like a pointed arch) projectiles dictate otherwise. In the lower part of figure 2–7 point *A* is the center of pressure of the surface being acted on by the air resistance, and *AB* is the line along which this force acts. The line *AB* meets the axis of the projectile at *A*, which point lies between the center of gravity and the point of the projectile.

An overturning moment is thus set up which tends to tumble the projectile, but the gyroscopic force of the projectile opposes this moment and tends to keep the axis in the original direction. According to the laws of the gyroscope, the action of the projectile, in attempting to overcome this overturning moment, must manifest itself in a PRECESSION of the projectile about the direc-

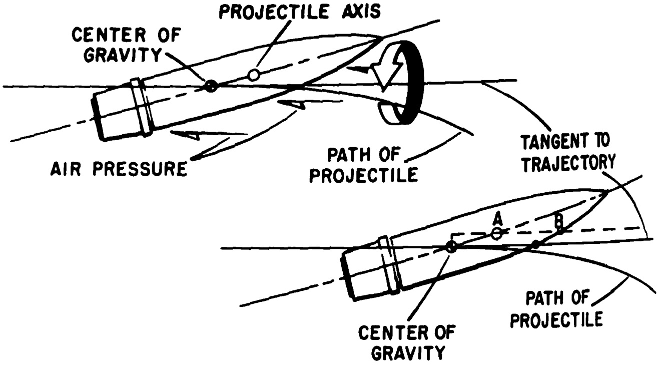


Figure 2–7.—Precession of a projectile in flight.

tion of the force which creates the moment. Also, in accordance with these laws, the precessional revolution of a projectile having right-hand spin, must be clockwise as viewed from the rear, as shown in the upper part of figure 2–7.

UNDERWATER BALLISTICS.—Shortly after the turn of the twentieth century several experiments were made to determine as nearly as possible the underwater ballistics, or trajectories, of naval gun projectiles after they had entered the water. Several nets were placed in the water at prescribed intervals, and projectiles were fired into the water directly ahead of the first of these nets. The conclusions drawn from these experiments were as follows:

1. For angles of impact of the shell with the water of less than about 8 degrees there will be a clean ricochet, the shell rising almost directly from the first point of impact with the water.
2. For angles of impact of from 8 to 14 degrees the shell actually enters the water, but leaves it again after an underwater travel which increases in length and maximum depth as the angle of impact increases. On impact with the water at a 14-degree angle, it was found that the projectile would not emerge again.
3. Between the angles of 14 and 22½ degrees, the

shells did not emerge but were found to turn upward until they ran horizontal or even turn upward until they ran above the horizontal under water for a while before sinking. As the angle increased beyond 22½ degrees, the underwater paths tended to become more and more a prolongation of their paths through the air.

It was further determined that projectiles which had ogival heads were likely to be more erratic in their underwater trajectory than those whose noses were flat. The flat portion of the nose tends to give stability to the projectile while under water. For this reason, most of our projectiles designed for underwater travel, such as the ASW rocket, etc., have either flat or bluntly rounded noses. There was one other determination of interest. This was that when a projectile ricocheted, the direction originally possessed by the projectile was changed to the right of the original direction. Undoubtedly this was due to the clockwise rotation of the projectile. These findings are still considered to be rather accurate today.

GRAVITY.—Gravity is one of the factors affecting the flight of a projectile, bomb, mine, rocket, and torpedo, as it leaves the gun, is dropped, or is fired. It commences to act on the missile the instant it is free in the air. The **GRAVITY DROP** acting on a projectile in flight varies with the speed of the projectile and the total distance it travels. Since speed is one of the major factors controlling gravity drop, each type missile will have a different value. Gravity drop is computed by the formula:

$$\text{Gravity drop} = \tfrac{1}{2} \times G \times T^2$$

where G equals the acceleration of gravity (32 feet per second per second), and T equals the time of fall in seconds. This formula was developed for conditions in a vacuum, but is sufficiently accurate for computing trajectories of projectiles, rockets, and bombs in still air.

AIR RESISTANCE.—Air resistance is another of the forces acting on a missile in flight. The primary effect of this resistance is one of slowing down the missile.

The effect of air resistance increases with the increase in the speed of the missile. Deceleration of the missile due to air resistance is most marked during the early part of the flight, and, as velocity decreases, the deceleration effect becomes less rapid.

The effects of air resistance to the passage of a missile was not overlooked by the early investigators. However, Newton seems to have been the first to have dealt quantitatively with this factor. He determined theoretically that the retarding of the missile due to air resistance must vary in proportion to the square of the velocity, PROVIDED diminishing pressure behind the missile and the airstream set up by friction were not considered. He tested his theory by dropping balls of various densities from the dome of St. Paul's Cathedral. He found that his theory held good for the rather low velocities he could obtain from this experiment. However, time showed that the effects of air resistance on a missile could not be reckoned by such a simple quadratic law as Newton proposed. In 1742, Robins worked with his "ballistic pendulum" which he arranged to absorb the force of a missile in flight. He measured the swing of the pendulum caused by the missile's force, and calculated its striking force therefrom. This system later proved to be accurate (or nearly so) up to velocities of 1,700 feet per second.

Later in 1840, Wheatstone suggested measuring velocities of projectiles by setting up successive wire screens for the projectile to cut in flight. These screens were placed in the electrical circuit which incorporated a time measuring device. From these experiments with the screens and a chronograph designed by a clergyman named Bashforth, a fairly accurate measurement of velocities was made in the years 1866–1870. Bashforth concluded that the projectile's cross sectional area was a definite factor in its resistance to flight in air. Wheatstone's work in electrical timing of the projectile in flight initiated the first real progress in the science of ballistics. His principles have continued up to this date as essential aids in the advancement of the science of ballistics.

Although the air resistance offered to a projectile while traveling at high speed is great enough to upset any calculations which do not take this fact into consideration, certain similarities exist between the trajectories in a vacuum and those in air. These similarities pertain to the general characteristics of the trajectory rather than to any quantitative values of the elements. The solution of trajectories in a vacuum is relatively simple, whereas the same solution under conditions of air resistance is very complex. The actual mathematical solution will not be considered in this course.

WIND (BALLISTIC).—It has previously been shown that drift causes a deflection of the projectile in flight. Another factor which causes an additional deflection is wind. Ballisticians use an arbitrary WIND WEIGHTING FACTOR which they apply to the winds measured in the different zones throughout the trajectory in which the projectile is to travel. The ballistic wind is therefore a fictitious uniform wind which is the equivalent of the several winds that actually exist within the limits of the trajectory. In other words, it is a weighted mean (average) wind which may be used for further calculations of trajectory and range.

If the ballistic wind is blowing from either side of the line of fire (at right angles to the line of fire), it will carry the projectile with it and cause some travel in the *ZZ* plane in relation to a fixed point on the earth. (See fig. 2–8 (A).) If the direction of the ballistic wind is the same as that of the projectile, the resulting effect is positive. In this case there will be less drag because the air is moving with the projectile and is offering less resistance to its motion. This is called a tailwind. (See fig. 2–8 (B).) If the direction of the ballistic wind is directly opposite to the travel of the projectile (headwind) the drag will be greatly increased, and a negative range effect will result as shown in the figure. The winds which result in either a headwind or a tailwind are known as RANGE WINDS.

Other winds which do not come directly from ahead or astern of the direction of travel of the projectile are called CROSS WINDS (lateral winds), and have no effect on range. However, the cross wind does have an added effect over and above that deflection caused by drift. The effects produced by cross winds are dependent on

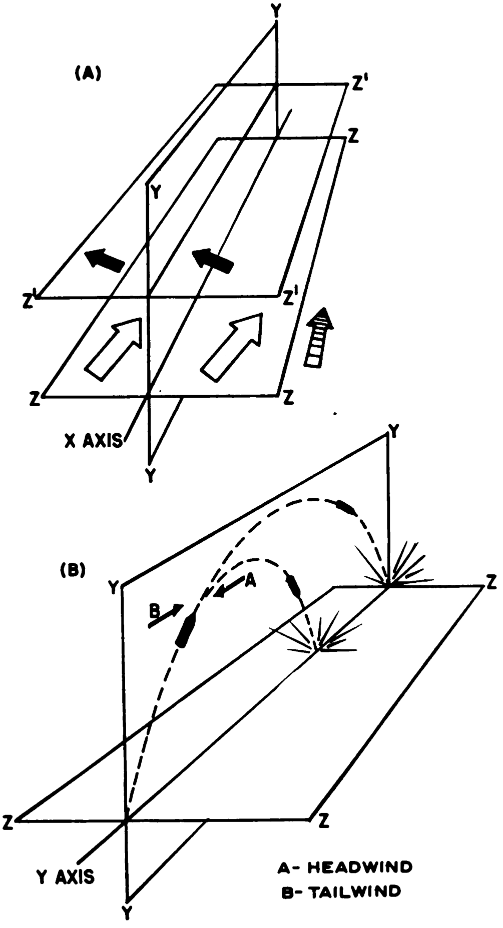


Figure 2–8.—(A) Ballistic wind; and (B) headwinds and tailwinds.

the direction and velocity of these winds themselves. For trajectories of short duration and time of flight, the ballistic wind is negligible, and corrections are not usually necessary. However, for trajectories of long times of flight the error must be compensated for, and firing tables are computed to furnish the necessary data to make proper corrections.

AIRCRAFT MOTION.—A gun fired from a moving aircraft causes the projectile to move in the same direction and with the same speed as it is being carried by the aircraft. This momentum is, of course, in addition to the speed of the projectile (muzzle velocity) itself. Also, this must be under conditions in which the gun is fired dead ahead, and the motion of both the projectile and the aircraft are thought of with respect to a fixed point on the earth's surface.

In cases in which the projectile is fired at an angle to the aircraft's line of flight, various values of the speed of the aircraft are additive, subtractive, or they cancel out in the determination of the total velocity of the projectile. It is easily understood that the projectile fired directly ahead will have a velocity (with respect to the earth) of the muzzle velocity of the gun (2,600 ft./sec.) PLUS the speed of the aircraft (300 ft./sec.). For the projectile fired dead astern, the velocity of the projectile will be the muzzle velocity MINUS the speed of the aircraft. For projectiles fired at intermediate positions between dead ahead and dead astern, the velocity of the projectile will be the vector sum of the velocity of the aircraft and the muzzle velocity of the gun. At some angle aft of directly abeam, the vector effect of the aircraft's velocity will be canceled, leaving only the muzzle velocity of the gun in effect. The resultant velocity will vary from the SUM of the velocity in the dead ahead position of the gun to the DIFFERENCE at the dead astern position. (See fig. 2–9.)

DEFLECTION, or the variation between actual trajectory and the bore axis of the gun, is always present

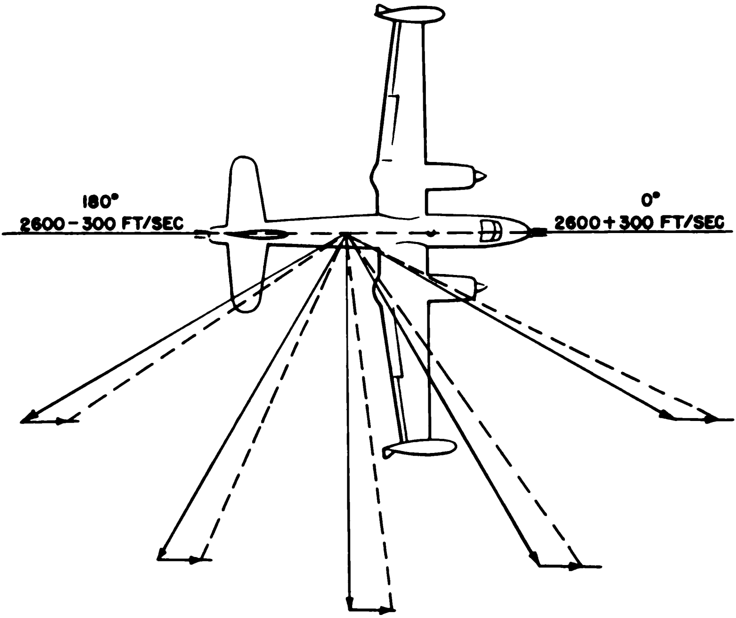


Figure 2–9.—Effects of aircraft motion on the projectile.

when firing to either beam. Figure 2–9 shows approximately the extent to which deflection is apparent for different angles to the longitudinal axis of the aircraft. It will be noted that deflection INCREASES from 0° to 90°, and DECREASES from 90° to 180°.

TRAIL.—In gunnery, the term TRAIL means the deflection from the projected axis of the bore of the gun, and is measured as the distance between the projectile, at any point in the trajectory of the projectile, and the bore axis of the gun. In bombing, the definition of trail is the horizontal distance at the height of the point of impact between the vacuum and the actual trajectory. Trail is due almost entirely to the only HORIZONTAL force normally acting on a bomb or projectile, which is the relative wind created by the speed of the aircraft. Hence, the bomb or projectile trails in the direction in which this wind blows. That is, it trails dead astern

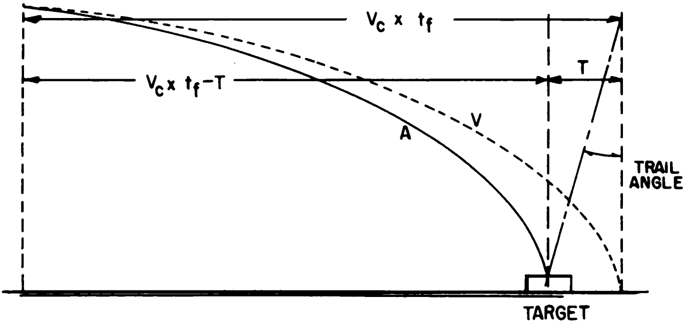


Figure 2–10.—Trail of a projectile in flight.

of aircraft's heading. Since for practical purposes, trail is caused by airspeed entirely, it will be the same for any given altitude of release regardless of whether there is a headwind, tailwind, or no wind.

In figure 2–10 there will be noted a horizontal displacement between the points of impact of a bomb dropped in a vacuum, *V*, and the one dropped in air, *A*. This displacement is trail, *T*. The range of a bomb in a vacuum is $V_c \times t_f$. A bomb released under vacuum conditions while on a track directly towards the target would fall over the target by a distance equal to the trail, *T*. In order to get a hit on the target, it is necessary to release the bomb at a range equal to $V_c \times t_f - T$.

It will also be noted from figure 2–10 that were the bomb to be dropped under a vacuum condition, the aircraft would be directly over the point on the ground which terminates the vacuum trajectory, *V*, as the bomb struck the ground. The drop in air, *A*, terminates on the target. Therefore, the ground distance, *T*, between the vacuum drop and the air drop is the trail, and the angle which is subtended by this ground distance is the TRAIL ANGLE.

JUMP.—The causes and effects of vertical jump have already been discussed in this course. The ANGLE OF JUMP is the angle described by the axis of the bore of the gun under the shock of firing, during the interval from the ignition of the charge to the ejection of the

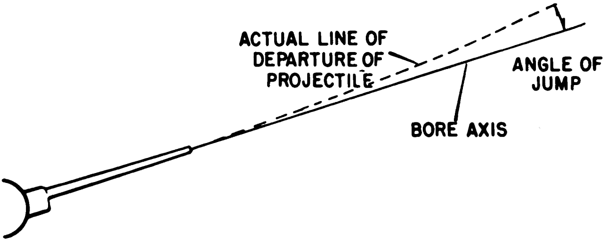


Figure 2–11.—Effects of jump on a projectile.

projectile from the muzzle of the gun. (See fig. 2–11.) Jump is considered POSITIVE when the muzzle of the gun jumps upward, and NEGATIVE when it jumps downward. Actually, this angle is nearly always positive, but not invariably so. The angle of jump in a well-designed gun is only a matter of a few minutes of arc, and remains reasonably constant in a particular gun for all angles of departure. This angle is considered in the computations for the range tables for the individual gun, so there is no need to be concerned with its calculation.

The effect of jump on the projectile fired from a moving aircraft causes the projectile to climb slightly when fired to the left, to veer slightly to the left when fired downward, to fall somewhat when fired to the right, and to veer slightly to the right when fired upward.

YAW.—Yaw is the angular deviation of the longitudinal axis of a projectile from its trajectory. It is caused by the irregularities of the projectile and the bore of the gun, and by the blast of the relative wind on the forward side of the projectile as it leaves the gun muzzle. The projectile has a tendency to wobble or spiral around its own trajectory. (See fig. 2–12.) Due to this yawing moment, the projectile is not being presented to the air exactly point first. This makes it necessary for the projectile to penetrate an area in the air which is greater than its actual diameter. Therefore, the projectile encounters a correspondingly greater resistance.

When the projectile moves through the air with its axis at an angle to the direction of its motion, as it does while yawing, the angle thus formed is called the ANGLE OF YAW. Yaw fortunately dampens out rather rapidly, and the most radical yaw tends to dampen out in the first second of flight, leaving the projectile in stable flight. The major effect of yaw is the slowing down of the projectile slightly. No allowance is necessary for this yawing effect as it is calculated into the speed of the projectile over various ranges.

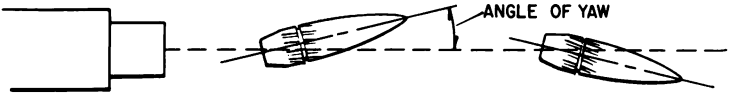


Figure 2–12.—Effects of yaw on a projectile in flight. (Exaggerated.)

THE VACUUM PROBLEM.—Calculations of trajectory are first made using a vacuum as the medium through which the bomb or other missile is to travel. As has been stated, this is the simplest method of determining trajectory. Since the force of gravity acting on a free falling body is 32 feet per second per second, the TIME OF FALL equals the square root of the distance divided by 4, or $t_f = \frac{\sqrt{d}}{4}$.

When a bomb is dropped from an aircraft in motion, it will retain the forward motion imparted by the aircraft. This motion remains constant in magnitude and direction when it occurs in a vacuum condition. The motion imparted to the bomb by the aircraft, plus the time of fall, determines the RANGE of the bomb. Range is the total HORIZONTAL distance the bomb moves forward from the time of release until its impact. In a theoretical case in which a bomb falls through a vacuum, there will be only two forces acting on it. These are gravity and the motion imparted by the aircraft. (See G and M in trajectory V of fig. 2–13.)

Since it is necessary to consider air resistance in order

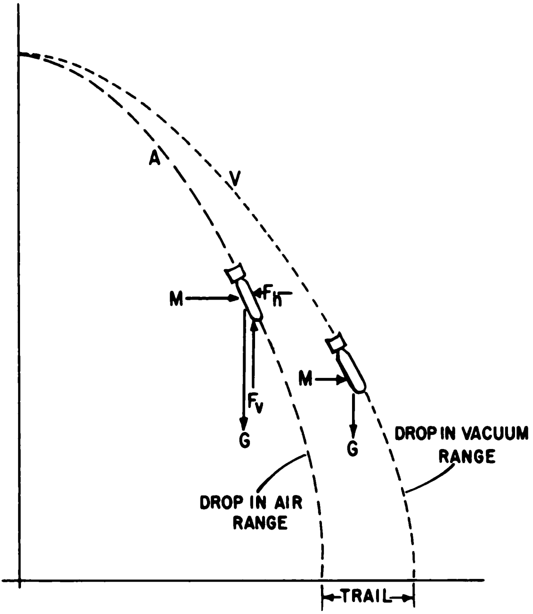


Figure 2–13.—Forces acting on a free falling body in air and in a vacuum.

to deal realistically with the problem of trajectory, it is necessary to cover the problem of trajectory through air. In air (trajectory *A*) these forces will be gravity, *G*, the air resistance in a vertical direction which opposes the force of gravity, F_v, the motion imparted to the bomb by the aircraft, *M*, and the air resistance in a horizontal direction which opposes the forward motion of the bomb, F_h. (See fig. 2–13.) The air resistance in the vertical direction causes the bomb to decrease in velocity at any instant during its fall, and thereby INCREASES ITS TIME OF FALL. Air resistance in the horizontal direction causes the bomb to TRAIL BEHIND THE VERTICAL from the aircraft.

COMPARISON OF VACUUM AND STILL AIR TRAJECTORIES. —A bomb dropped in still air will lag behind one dropped in a vacuum with regard to their respective points of impact on the ground. The theoretical one dropped from an aircraft in a vacuum, having no air resistance to oppose its flight, will have a greater horizontal displacement on the ground than the one dropped in still air. In other words, the trajectory of the bomb dropped in still air will LAG the trajectory of the bomb dropped in a vacuum. This lag causes a difference in the distance between the two drops. This difference is known as GROUND LAG, and is not to be confused with trail. Trail, as you will remember, is the horizontal distance between the still air trajectory and the vacuum trajectory AT THE SAME INSTANT OF TIME. Trail is always measured astern of, or opposite to, the aircraft's direction of flight. The amount of trail is governed by the aircraft's ground speed at the time of release, and the length of time the air resistance acts on the bomb or the time of fall. This latter factor is determined by the altitude at which the bomb is released.

Trail and time of fall of a bomb are determined as each type of bomb is actually calibrated at the proving grounds. Tables are compiled which show these factors for each bomb type. From these tables, trail and the time of fall may be determined for any point in the bomb's trajectory.

When the aircraft is headed either directly into the wind or downward, its course over the ground is the true course flown. In other words, it makes its own course good over the ground. In all other conditions of wind direction the course steered will not be the actual course over the ground. Therefore, there will be an angle formed between the course the aircraft is steering and the course it makes good over the ground. This angle is called the DRIFT ANGLE, or angle of drift. The drift angle is tied in with another factor called CROSS TRAIL. Cross trail is the distance the bomb falls toward the downwind side of the target (*EB*) due to the combination of the drift angle and the natural trail of the bomb. (See fig. 2–14.) To compensate for cross trail, it is necessary for the aircraft to fly a course (Course *AD*) which takes it to the upwind side of the target a

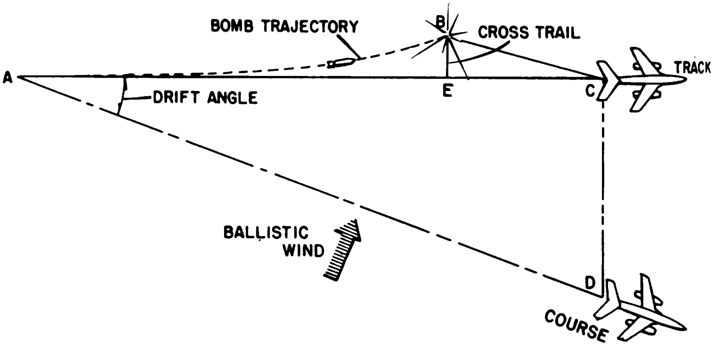


Figure 2–14.—Drift and cross trail.

predetermined amount, or a distance which corresponds to the amount of cross trail existing.

As target motion in the same direction or opposite direction to the aircraft's line of flight is considered as either a headwind or tailwind for purposes of calculation, target motion ACROSS the line of flight may be considered a CROSS WIND. This cross wind is compensated for when making the necessary computations for drift angle and cross trail, as well as other factors in the bombing problem.

The range of a bomb in a vacuum is equal to the velocity of closing, V_c, multiplied by the time of fall, t_f. Due to the fact that a bomb dropped in air lags behind one dropped in a vacuum by an amount called trail, T, the range of a bomb dropped in air is equal to the vacuum range minus the trail, or $R(Air) = V_c \times t_f - T$. (See fig. 2–10.)

Since there is hardly a condition in which atmospheric conditions permit perfectly still air in which to bomb, we have to consider trajectories through air in movement. If the bombing run is made either directly upwind or downwind, both the range and ground lag are almost wholly governed by the force and direction of the wind and the target motion. Target motion in either the same or opposite direction to the true course of the aircraft gives the same results as a headwind or a tailwind of the same velocity. The velocity of closing is governed by a combination of airspeed, wind direction, and speed of the target (motion), if present.

TYPICAL BOMBING PROBLEM.—In order to better visualize what has been previously discussed, a typical bombing problem is herewith depicted. When a bomb is released from an aircraft in level flight, the bomb will have the same initial forward speed as the aircraft but will have no vertical speed. The bomb will meet resistance from the air, and will receive resistance or assistance from the winds, depending on their direction. As the bomb is drawn to earth by the gravitational force, its speed increases at a definite acceleration, up to a certain point. When this point is reached, acceleration commences to decrease, and continues to do so until there is no acceleration. At this point the bomb continues to fall at a constant velocity until it reaches its impact point. **TERMINAL VELOCITY** is said to exist when the bomb no longer accelerates during the fall.

During the fall of the bomb, it is acted upon by the density of the air (density in turn is affected by temperature) and the wind forces which may be from any quarter. If you could see the bomb throughout its flight, it would initially be seen to retain a horizontal position under the aircraft for a portion of the flight and then to nose over slowly as it falls away. As the acceleration increases, the angle between the longitudinal axis of the bomb and that of the aircraft becomes greater depending on the time of flight. However, due to the configuration of modern bombs and the speeds of present day aircraft, this angle will never actually become 90 degrees. As the bomb gains greater downward velocity, the forces of resistance exert greater pressures and force the axis of the bomb more and more towards the earth. As the bomb nears the end of its trajectory, or nears the earth, the curve of its trajectory falls off much more rapidly than earlier in the trajectory, and the curve becomes more pronounced. It has already been shown

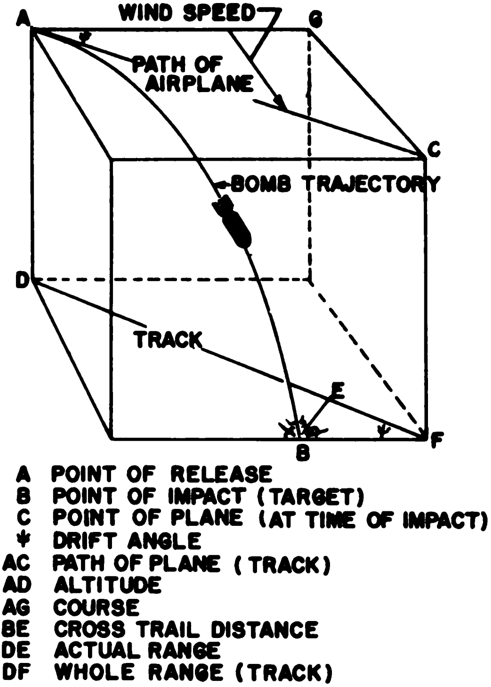


Figure 2–15.—Typical bombing problem.

that the bomb will lag behind the aircraft from which it was dropped as it loses its forward speed. When the bomb finally strikes the ground it will have lagged a considerable distance behind the aircraft. This distance is known as trail, or the distance, *BF*, in figure 2–15. The angle made by a line from the aircraft to the point of impact of the bomb and a vertical line from the aircraft to the ground form what is known as the TRAIL ANGLE. (See fig. 2–10.)

Ordinarily, an aircraft on a bombing run will encounter lateral winds. In order to bring the aircraft over the proper dropping point, it will undoubtedly be necessary to alter the course of the aircraft to compensate for these winds which tend to set it off its course to the target. The same effect is transmitted to the bomb in flight by these lateral winds, and will cause its point of impact to be downwind from the track of the aircraft, at point *B* in figure 2–15. Therefore, the distance, *BE*, is the cross trail. The stronger the lateral winds, the greater will be the cross trail.

In closing this discussion on exterior ballistics, it might be well to say that accuracy of long range firing and high altitude bombing is a relative matter. The claims you may have heard of the ability of pilots to hit with every round and to drop bombs in a pickle barrel from 20,000 feet are actually eloquent exaggerations. Under the most ideal conditions a certain amount of dispersion will occur. Under normal conditions, which considers the natural factors of weather, materials, and human elements, precise determinations and corrections are not made with any great degree of consistency. Thus it is, that for every type of weapon, projectile, and bomb, there is a "probable error" of measurable size which may be determined experimentally. An estimate may be made from these "probable errors" by which may be determined the number of rounds, bombs, and rockets necessary to destroy a given target. An added safety factor is usually assigned to this estimate to insure sufficient armament for the job at hand.

QUIZ

1. That subject not covered in the study of interior ballistics is
   - a. type of powder
   - b. heat cracks
   - c. projectile free flight
   - d. adiabatic expansion

2. Exterior ballistics deal with projectile motion
   - a. in the gun chamber
   - b. through the earth's atmosphere
   - c. through the gun bore
   - d. none of the above

3. Mathematical solutions to the exterior ballistics problem were developed during the 18th century by
   - a. Euler
   - b. Tartaglia
   - c. Newton
   - d. Galileo

4. Computations for the elastic strength of the gun are associated with
   - a. service condition
   - b. ballistic condition
   - c. mechanical condition
   - d. all of the above

5. A progressive explosive used as a single base propellant is made from
   - a. diphenylamine
   - b. nitroglycerin
   - c. nitroglycerin and nitrocellulose
   - d. nitrocellulose

6. A progressive explosive that may become a high explosive after freezing is made from
   - a. diphenylamine
   - b. nitroglycerin
   - c. nitroglycerin and nitrocellulose
   - d. nitrocellulose

7. Gradual enlargement and smooth wearing away of the surfaces of the bore of a gun is called
   a. scoring
   b. abrasion
   c. heat cracking
   d. erosion

8. Bore wear caused by hot gases bypassing the projectile where defects or scratches exist in the bore is termed
   a. scoring
   b. abrasion
   c. heat cracking
   d. adiabatic expansion

9. Forces and actions produced during projectile bore travel which do not fall in any specific category are termed
   a. exterior ballistics
   b. transitional ballistics
   c. interior ballistics
   d. none of the above

10. A factor not considered in the study of exterior ballistics is
    a. gravity
    b. air resistance
    c. wind
    d. adiabatic expansion

11. Relative wind created by the speed of an aircraft produces projectile deflection called
    a. yaw
    b. jump
    c. trail
    d. drop

12. Irregularities of a projectile or gun bore and relative wind blast produce projectile wobble or spiral called
    a. yaw
    b. jump
    c. trail
    d. drop

13. When computing the trajectory of any projectile using the vacuum problem, the only two factors considered are
    a. gravity and air resistance
    b. gravity and aircraft motion
    c. air resistance and aircraft motion
    d. none of the above

CHAPTER 3

AIRCRAFT GUN SYSTEMS

AIRCRAFT GUNFIRING CONTROLS AND CHARGING SYSTEMS

Hydraulic and Pneumatic Charging Systems and Their Controls

The aircraft gunfiring controls and charging systems of the present day military aircraft are complicated components of the overall electrical, hydraulic, and pneumatic systems of these aircraft. Study is necessary to comprehend how and where the components of the gunfiring control and gun charging fit into the general scheme of the aircraft's systems. In the study of gunfiring controls and gun chargers, it is logical to divide them into two systems: one in which hydraulics is used, the other in which compressed air is used. Each of these systems will have its associated electrical control components.

It will be noted that the legend for figure 3–1, which contains elements of the HYDRAULIC CHARGING SYSTEM—FIRING CONTROL combination, is shown on the page opposite figure 3–1; and those of the PNEUMATIC CHARGING SYSTEM—FIRING CONTROL combination appear on the page opposite figure 3–2. Neither of these two combinations constitutes an actual or even a typical hydraulic-pneumatic charger system with its associated firing controls. This is due to the fact that various elements have been added which are not all common to any one given system, but which are to be found in various other installations. There are other interconnected components such as search radar, fire and/or armament controls, and others normally discussed in association with gunfiring controls which are not detailed in this chapter. They have purposely been omitted in order not to complicate the explanation of the firing controls and chargers.

PNEUMATIC GUN CHARGER AND ITS GUNFIRING CONTROLS.—As the word PNEUMATIC implies, compressed air is the actuating force used with the electrical controls to form this pneumatic gun charger and control system. Since it would be highly inconvenient to operate any aircraft gun system by opening and closing the controlling air valves manually, electrical gunfiring controls have been made to perform these duties. Further, since electricity controls the charging and firing of the guns, discussion of the system will commence with the electrical controls and the sources from which they derive their power.

For the sake of clarity and ease of discussion, all components of this system have been assigned numbers which follow each component in parentheses, and which refer the reader to corresponding numbers in the respective legends for figures 3–1 and 3–2. It will be noted in both legends that most of the components listed in the early portion are identical for both the hydraulic and pneumatic charging systems. In the few instances in which components have differing nomenclature, through item 42, the functions of these components are sufficiently identical to warrant comparison. From item 43 forward, the components listed in the legends are peculiar to either the hydraulic or the pneumatic charger system and not common to both. For the above reasons, the description of the hydraulic charger system will parallel that of the pneumatic system throughout the earlier portions of this discussion. Although the discussion of both the hydraulic and pneumatic gun charging systems will, at times, parallel each other, alternate circuits and different sources for derivation of power will be discussed. This indicates that there are a number of equally suitable methods of hooking up the firing

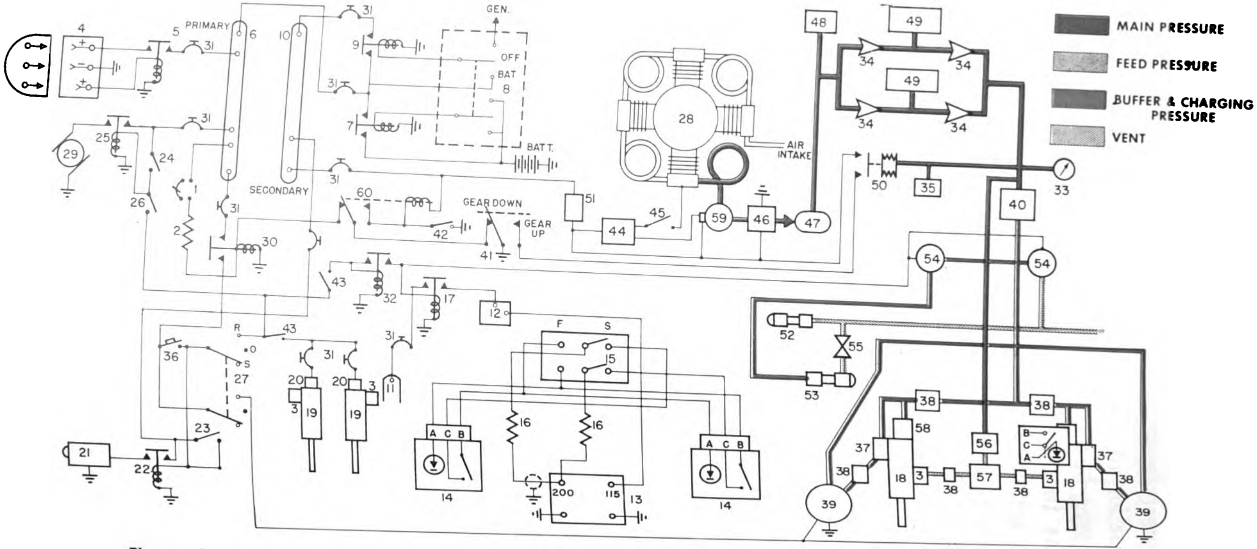


Figure 3—1.—Schematic diagram of hypothetical pneumatic gunfiring control and gun charging system.

Nomenclature for figure 3—1

Nomenclature for figure 3—1

1. Armament master switch.
2. Master switch safety resistor.
3. Gun feed mechanisms.
4. External power receptacles, 27.5-volt, d-c.
5. External power relay.
6. Primary bus.
7. Battery relay.
8. Electrical power control switch.
9. Secondary bus relay.
10. Secondary bus.
11. 115-volt bus.
12. Radio noise filter.
13. Transformer.
14. Synchronizing switches.
15. FREE-SYNCH switch.
16. Transformer resistor.
17. Gunfiring relay (115 volts).
18. Guns (electric primed ammo).
19. Outboard and inboard guns (percussion ammo).
20. Gunfiring solenoids.
21. Gun camera.
22. Gun camera relay.
23. Gun camera test switch.
24. Manual booster switch.
25. Booster relay.
26. Booster micro switch.
27. READY-OFF-SAFE switches.
28. Pneumatic compressor.
29. Ammo booster (electrically driven).
30. Armament power relay.
31. Circuit breakers.
32. Gun charging firing control relays.
33. Pressure gage or warning light.
34. Pressure check valves.
35. Relief valve.
36. Gun trigger switch.
37. Gun chargers.
38. Quick disconnects.
39. Charger solenoid control valves.
40. Charger pressure regulator.
41. Landing gear handle relay.
42. Armament disabling switch.
43. Gun selector switches (inboard and outboard).
44. Peak power cutout.
45. Compressor control switch.
46. Moisture separator.
47. Chemical air drier.
48. Filler valve.
49. Compressed air bottles.
50. Pneumatic pressure switch.
51. Compressor noise filter.
52. Vent inlet door cylinders.
53. Vent outlet door cylinders.
54. Vent solenoid valves.
55. Restrictors.
56. Feed mechanism pressure regulators.
57. Feed mechanism manifolds.
58. Buffers.
59. Vent valve.
60. Gunfiring override relay.

controls for the guns of both the hydraulic and pneumatic gun charger systems.

In order to supply power to the aircraft's gun control system, it is necessary to close either the electrical power control switch (8), or plug in an external power supply to the aircraft's external power receptacle (4). If the electrical power control switch is turned to BATTERY, power is directed to the battery relay (7), and thence to activate the primary bus (6), the secondary bus relay (9), and the secondary bus (10). In this manner the primary and secondary buses become the power sources for the gunfiring controls. When the external power source is connected to the aircraft's external power receptacle, the short contact of the plug, making connection inside the receptacle last, closes the external power relay (5). This short contact, in making connection last while plugging in and breaking the connection first while unplugging, greatly reduces the chances of arcing of the contacts, thus giving longer life to the contacts and reducing the chances of sparks igniting vapors in and around the aircraft. When the external power relay closes while the electrical power control switch (8) is in the OFF position, power is supplied to circuits of the primary bus. When this switch (8) is turned from OFF to BATTERY or GENERATOR-BATTERY, power is supplied to the secondary bus by the closing of the secondary bus relay (9).

One may assume that all of the power supplied to the firing control and gun charging systems comes through the armament power relay (30). However, for reasons to be shown later, several circuits like those for the gun camera (21), electric ammunition booster (29), gun charging, and others derive their power from a source ahead of the armament power relay through circuit breakers (31), as well as THROUGH this relay.

The armament power relay furnishes power to most of the main armament circuits from the primary bus (6). It is controlled and operated by the master armament switch (1) which in effect is a circuit breaker. The control of the armament power relay by the master armament switch is devised for a definite purpose, and this purpose is to operate the safety circuit of the gunfiring system with a minimum of current. When the pilot lowers the wheels preparatory to landing, this action closes the landing gear handle relay (41) which performs the operation of grounding out the master armament switch through a resistor (2), opening the circuit and safetying the gun chargers and gunfiring controls of the aircraft. The master armament switch is also grounded in aircraft when the tailhook is lowered. A micro switch tied in with the actuation of the tailhook performs this safety function. To control the amount of current at the master armament switch, the resistor is placed in the line. This resistor protects the master armament switch and allows only enough current to flow to actuate the master armament switch circuit breaker.

When actuated, the armament power relay operates the gun charger controls and supplies power for firing the guns when the gun trigger switch (36) is depressed. Although one contact of the gun trigger switch has power supplied to it, depressing the switch will not fire the guns if the READY-OFF-SAFE switch (27) is positioned at either SAFE or OFF. With the READY-OFF-SAFE switch in the SAFE position, the gun charger control solenoid valves (39) are deenergized. THESE VALVES ARE VENTED WHEN ENERGIZED. Since they are NOT VENTED when the READY-OFF-SAFE switch is positioned on SAFE, the bolts of all guns will be charged to the aft position and held there by the 1,000 p.s.i. from the compressed air source. The READY position provides power to the inboard and outboard gun selector switches (43). The READY position also supplies pneumatic pressure to the charger control solenoid valves (39) which control the charger's pneumatic pressure. When the charger control valves are actuated, an electrical valve within cuts off the 1,000 p.s.i. pressure to the forward ends of the chargers and vents the pressure ALREADY accumulated on the forward ends of the charger pistons, and the continuous pressure on the rear of the chargers brings them forward.

In the pneumatic gun charging system, the selector switches (43), when energized, supply power to the gun charging firing control relay(s) (32) as the gunfiring trigger is depressed. There are two vent solenoid valves. The NORMALLY CLOSED solenoid valve (54), when actuated by the gun charging firing control relay, closes off the high pressure (1,000 p.s.i.) line from the compressed air system and vents the inlet and outlet door cylinders (52) and (53). The NORMALLY OPEN vent solenoid valve closes simultaneously and permits high pressure air to flow into the other ends of the vent inlet and outlet door cylinders thus opening them. Upon release of the gun trigger switch, the two vent solenoid valves reverse their action, causing the normally closed valve to open allowing the high pressure air to charge the other ends of the inlet and outlet door cylinders. At the same time, the normally open vent solenoid valve closes permitting the air to escape slowly through the restrictor(s) (55). The inlet door cylinders operate quickly, but the outlet door cylinders are made to close more slowly by the restrictors in order to completely scavenge the gases of combustion from the gun compartments.

In addition to actuating the vent solenoid valves, the gun charging firing control relays (32) also supply 28 volts, d.c. to the gunfiring relay(s) (17). These relays control the voltage from the 115-volt, a-c bus (11), to the transformer (13), through the noise filter (12). The transformer boosts the 115-volt power to 330 volts d.c. This 330-volt power is then supplied to the FREE-SYNCH switch (15) through the transformer resistor (16). This resistor is placed in the line in order that the other gun can continue to fire even though one lead is shorted. The FREE-SYNCH switch will operate the guns in either free or synchronized fire. In the FREE fire position the 330 volts are applied directly to the synchronizing switches (14), causing the guns to fire each time a bolt makes contact through the bolt's electrical circuit (330 volts) to the primer of a round in the chamber. In SYNCH firing, opposing pairs of guns are wired so that when their bolts are in the BATTERY position, both guns of the pair will fire simultaneously ONLY. The slower gun of the two will control the rate of fire.

Both turret guns and those installed in fighter aircraft may be synchronized to fire simultaneously. Currently, only the turret guns are synchronized.

In an above paragraph it was noted that several components with their circuits received their power from a source ahead of the armament power relay (30). These are the gun camera (21), the electric ammunition booster(s) (29), and the circuit which fires the electrically fired ammunition. These components have been added to the schematic in order to show that they may be used with either the guns which fire the electrically primed ammunition (18), or those which fire the percussion primed ammunition (19). In figure 3–1 the gunfiring solenoids (20) are used on percussion primed ammunition guns.

The ammunition boosters (29) are installed at some point along the ammunition chuting between the ammunition cans and the guns. Regardless of the actual point of attachment, the boosters are solidly mounted to prevent movements other than that of the control spring operating movement. They are used, when installed, to pull the heavy belted ammunition through long ammunition chuting from the cans and aid in getting this ammunition to the guns. With the battery switch (8) turned to the ON position, the booster manual switch (24) energized, and the armament power relay (30) in the OFF position, the boosters will operate while on the ground. While in the air, the boosters go into operation when the feed mechanisms (3) place a strain on the belted ammunition. This causes the spring-loaded booster micro switch (26) to be energized. Closing of this switch activates the booster relay (25) which starts the boosters to operating. The boosters run until they have pulled enough ammunition from the cans to supply the guns and relieve the tension on the feed mechanisms. At this point, the tension on the boosters' spring-loaded mount being relieved, the micro switch returns to its normally open position, causing the booster relays to deenergize and stop the booster action.

The mounting brackets of the boosters are spring loaded, and have the micro switches (26) connected to them. Both the booster manual switches (24) and the booster micro switches (26) cause the booster relays (25) to activate the boosters when they are closed. The manual booster switches are for use on the ground while loading ammunition. The booster micro switches operate automatically while in the air as the spring-loaded mount is moved by the pull on the belted ammunition by the feed mechanisms. Some electric ammunition boosters have a clutch incorporated which may be manually operated to disengage the star wheel. By disengaging this star wheel, the ammunition may be more easily passed through the booster during loading of the guns.

The current for operation of the electric boosters comes from two sources. The manual booster switch(es) receive their power from the primary bus (6), through a circuit breaker (31). Power for the micro booster switch(es) is derived from the READY-OFF-SAFE switch (27) READY position in figure 3–1, but is taken from other points in other installations. As explained above, current from both these switches control the booster relays to operate the boosters.

The gun camera (21) is operated by current from the gun camera relay (22). This relay receives its power from the secondary bus (10). Actuation of the gun camera relay is brought about in two ways, through two separate circuits. In one circuit, the gun camera test switch (23) is connected through a circuit breaker to the secondary bus bypassing the master armament circuit. The reason for bypassing the master armament circuit is to be able to test the gun camera without energizing the gunnery system. (There have been instances of automatic fire of the guns when the gun cameras were improperly connected into the circuit.) In the other circuit, the gun camera is operated by power from the gun trigger switch (36). In the arrangement of the system as shown here, it would be possible to operate the camera in a simulated gunnery run by turning on the armament master switch (1). Then, when making the simulated run by depressing the gun trigger switch (36), the camera records photographically the number of "hits." Gun cameras are provided with an overrun feature which continues the operation of the camera for a predetermined number of seconds after release of the trigger switch.

Most of the components of the aircraft gunfiring controls are fed by the armament power relay. There are other circuits, however, which take their power from a point, or points, ahead of the armament power relay, thus bypassing this relay. One of these circuits contains armament disabling. The function of this circuit is to deenergize the safety circuit of the aircraft in order that tests and inspections may be performed on the aircraft armament while it is on the ground. It will be remembered that as soon as the landing gear is actuated for use, the armament safety circuit is activated. This special circuit is made inoperative on the ground through operation of the disabling switch (42). This switch is of momentary construction and is located outside of the cockpit for actuation by ground personnel. When it is closed, 28-volt d.c. is supplied to the gunfiring override relay (60). Upon closing, this relay shifts the ground from the armament safety circuit to the gunfiring override relay, thus providing a holding circuit. This holding action causes the gunfiring override relay to remain closed even after the momentary disabling switch has opened its own contacts. The override relay will remain closed until the aircraft power (28-volt d.c.) is interrupted.

The pneumatic air compressor (28) and its components will be discussed next. These elements do not derive their power through the armament power relay but from the primary bus (6) through a noise filter (51) and compressor control switch (45). The compressor is provided with a pneumatic pressure switch (50) which is regulated to energize the compressor motor at a pressure of 2,750 p.s.i., plus or minus 50 p.s.i., and to deenergize the motor when the pressure has been elevated to 3,000 p.s.i., plus or minus 50 p.s.i. The pneumatic pressure switch is capable of operation through 10,000 complete cycles at a minimum without failure. The power consumption of the compressor does not exceed 70 amperes within the voltage range when operated at sea level ambient pressure, and at an output pressure of not less than 3,000 p.s.i. A peak power cutout (44), supplied as a separate unit for certain designated aircraft, is capable of turning off the compressor motor when the current demands required by the compressor and the other electrical equipment of the aircraft exceeds 100 amperes.

It is not unusual in present day aircraft to have as many as three separate compressed air systems supplied by the main compressor. In such cases each system will contain emergency air bottles with their associated check valves. These check valves isolate these systems in the event of failure of the main compressor system. In addition to the main compressed air system used to actuate the gun chargers, the supplementary systems are generally used in emergencies to actuate such components of the aircraft as the landing gear, canopy ejection, wheel brakes, and sometimes to control nosewheel steering. These supplementary compressed air systems are brought up to pressure by the main compressor (sometimes by a supplementary compressor) and held at a predetermined pressure in the event of compressor failure. The previously mentioned check valves perform this function of isolating the compressed air in the bottles.

The term HIGH PRESSURE AIR is only relative because there is no recognized "standard" high pressure air level as such. High air pressure may then be considered as any figure between 50 p.s.i. and one that runs into five figures. However, in dealing with high pressure air systems in aircraft, it will be assumed that 1,500–3,000 p.s.i. is the maximum pressure. Although this figure is not high with respect to ultimate air pressures, the pressures found in aircraft systems is dangerous if not properly understood and correctly maintained. No attempt should ever be made to work on or remove components from a high pressure system without first bleeding the system. Serious injury to personnel and damage to aircraft can occur by working on a completely charged system.

The air compressor (28) currently used is typically a four-stage, self-contained, fan-cooled unit with a compressing rate of 2 cubic feet per minute and a maximum output pressure of about 3,000 p.s.i. This compressor maintains an operating pressure (for all uses) in the air bottles. It is equipped with pressure controls, interstage coolers, moisture separator, aftercooler, radio interference suppressors, and a receptacle for connection to a 28-volt power source. The compressor is capable of charging a pressure reservoir with a capacity of not more than 100 cubic inches to a pressure of 3,000 p.s.i. within a maximum time of 6 minutes. The recharge time to raise the pressure from 2,700 p.s.i. to 3,000 p.s.i. under the identical conditions is not more than 45 seconds. A lubrication system is incorporated within the compressor. This system requires changing of the oil after every 30 hours of operation. A removable plug fitted with a bayonet gage to indicate the oil level permits renewal or replenishment of the oil supply.

Air is led into this compressor at the #1 cylinder at which point the first stage of compression occurs. This partially compressed air is led to the #2 cylinder through an intercooler where the second stage of compression occurs. The third stage of compression occurs after the air passes through intercooler #2 into cylinder #3. A differential pressure relief valve in the #3 cylinder senses the #2 intercooler pressure and prevents excessive compression ratios in the #3 cylinder in the event that the #4 cylinder should fail to operate. The compressed air then flows through intercooler #3 into cylinder #4 where the fourth and final stage of compression takes place. From cylinder #4 the highly compressed air flows through the aftercooler and enters the pressure control and moisture separator. Here the moisture is removed from the compressed air and vented to the atmosphere through the moisture blowoff tube. Now that the air is compressed it passes through the vent valve (59), moisture separator (46), and the chemical air drier (47), through check valves (34) to the air bottles (49).

A filler valve (48) is in the line between the moisture separator and the chemical air drier. When the compressor is turned off, the vent valve (59) (normally opened, but closed while compressor is running) opens and allows the residual pressure in the compressor to be vented to atmosphere. The moisture separator (46) incorporates a thermostat and two heaters, and filters the moisture from the compressed air. Moisture is automatically drained from the separator. The thermostat closes at 35° F. and opens at 70° F. The highly compressed air leaves the moisture separator and enters the chemical air drier. This drier contains silica gel which absorbs the remaining moisture in the compressed air before it enters the reservoir. The silica gel is contained in a cartridge which is replaced each 25 hours of operation.

Prior to entering the reservoir, the compressed air passes through a series of check valves (34). In order to have a reserve supply of highly compressed air as well as a storage point for the air from the compressor, reservoirs (air bottles in this case) are placed downstream from the check valves. These reservoirs of necessity have to be carefully manufactured to service specifications. If they were not specially constructed, and should they receive a hit from gunfire, they would likely explode with terrific violence. They are constructed so that, if hit, a sizeable portion of the bottle may be torn away without the entire bottle rupturing. They are called "nonshattering." Production tests are performed during manufacture which subject the bottles to pressures greater than ever to be experienced in service operation, and careful checks for leaks are made. The size, shape, and general construction features are dictated by the installations into which they will fit, and by the maximum capacity of the compressors with which they are used. Working around and with these bottles while they are under pressure constitutes a hazard. They should be handled carefully despite the fact that they are practically nonshatterable.

The filler valve (48) is essentially a check valve in that air from an exterior source is applied to this valve in order to fill up the aircraft's system. As the external source is connected, the valve allows this pressure to flow into the system provided the external source is under greater pressure than the aircraft's system. As soon as the external source is disconnected, the filler valve closes to trap the increased pressure inside the system.

The purpose of the air compressor (28) is to furnish the necessary air pressure for operation of the various units of the aircraft while airborne. In order for the compressor to operate at maximum efficiency, all of the air bottles should be topped off from an external source before the aircraft leaves the line. In this way the compressor will not have to top off the bottles itself, and the system will be ready for instant use.

Downstream from the air bottles are the relief valve (35), the pressure gage (33), and the pressure switch (50). The relief valve acts to vent any pressure in the system above that needed for the system. The pressure gage simply measures the total applied pressure on the system at any one given time. The pressure switch is pneumatically operated when the pressure in the system builds up or drops off from preset values. When the pressure switch opens, the compressor is automatically deenergized. If the system pressure drops below a set value, the pressure switch closes the contacts in the compressor circuit starting the compressor and builds up the necessary pressure in the system.

The gun charger pressure regulator (40) and the feed mechanism pressure regulator(s) (56) are next downstream on the high pressure line of the system. The gun charger pressure regulators receive the high pressure air and reduce it from about 3,000 p.s.i. to a pressure sufficient to operate the gun chargers. The feed mechanism pressure regulators also reduce the same high pressure air to a working pressure sufficient to operate the feed mechanisms. In the pneumatic charging system described here, 3,000 p.s.i. has been shown as the maximum. However, there are other systems used for the same purposes which operate under different maximum pressures and employ different types of compressors. As an example, one of these systems employs a compact hydraulic motor instead of an electrical motor to drive the compressor.

The reduced air pressure which leaves the gun charger pressure regulator (40) is led to the gun buffer (58) which absorbs the shock of the bolt and returns it to battery during firing of the guns. The reduced pressure from the gun charger pressure regulator also furnishes pressure to the vent solenoid valve (54). The feed mechanism pressure regulator furnishes reduced pressure to the feed mechanism manifold(s) (57). These manifolds supply the feed mechanisms (3). The feed mechanisms are attached to the manifolds by quick disconnects (38) and high pressure hoses for ease in replacing the guns and their attachments.

The pneumatic feed mechanisms currently in use are compact units which fit closely to the tops of the guns.

They are constructed so that they are capable of converting air pressure into a reciprocating linear mechanical motion within the mechanism, which pulls the belted ammunition through feed mechanism, strips the links off, and positions the delinked rounds in the feed throat where they are available to be picked up by the forward moving bolt.

The gun chargers (37) are essentially pneumatic tubes which are fastened to the gun receivers (18) parallel to their longitudinal axis. One type, by allowing air pressure to enter the charger through a port, causes this pressure to act against an enclosed piston which is connected to the moving gun bolt slide. This action forces the bolt to the rear, extracting and ejecting the spent round. The action is now reversed as the pressurized air is vented from the head of the piston through a dumping valve. A spring on the charger piston returns it to the forward position. In another type, the piston is double acting. In this double-acting type, the piston is forced in one direction by porting compressed air to one end of the piston head, and forced in the opposite direction by porting the air to the opposite end of the piston head. This system is the more positive because no reliance has to be placed on a spring to return the piston to its normal position.

In one of the current 20-mm guns, the gun charging device is made as an integral part of the gun receiver. Being integral, the charger cannot possibly become loose or out of alignment, and its inherent strength is much greater than the detachable type. It is also a double-acting type charger, and positive action in both directions is assured to a much greater extent than in the single-acting charger with spring return.

HYDRAULIC GUN CHARGER AND ITS CONTROLS.—It will be noted that the listing of components which make up the hydraulic and pneumatic charger systems are identical in numerous cases. In those few instances in which items (1) through items (42) differ in nomenclature for opposing items, it will be found that the components in question serve identical purposes. It will be further noted that from items (43) onward, the components listed are peculiar to either one system or the other and not common to both. Due to the above reasons, the description of the hydraulic system will parallel that of the pneumatic system throughout the earlier portions of the discussion. Alternate circuits and different sources of power derivation will be shown in discussing the hydraulic system. This is done to show that there are other equally suitable methods of arranging the firing controls of the gun system.

For several years the Navy has employed hydraulic power to charge aircraft guns. It has proven to be a successful method. The vital merits of both the pneumatic and hydraulic gun charging systems are currently being tested in the field as both systems are in daily use. As far as is known, neither system has been, or is likely to be, selected for service use to the wholesale exclusion of the other.

There are various methods of getting power to the gun control system. As an example, one method is to construct the control system so that there is a main bus and one or more auxiliary buses (radio, radar, armament, etc.) which furnish power to this system. Further alterations may be made so that the external power source cannot be supplied to the system without the battery being installed in the line. In such an installation, the battery relay, actuated by the battery switch, closes an auxiliary power supply relay incorporating a holding circuit. (A HOLDING CIRCUIT is so designed around a relay that a set of contacts of the relay are wired to furnish power to keep the relay closed once it is actuated. Normally, actuation of this circuit is accomplished by another circuit incorporating a momentary switch to a power source.) Once this holding feature is actuated, the battery may be removed from the circuit or left remaining if additional power is necessary. As long as the external power source is not interrupted, the holding relay will continue to remain closed. If it is interrupted, the holding relay will open and will require that the battery again be used to close it.

In the system shown in figure 3–2, the hydraulic gun charger control system, power is received from either an external power receptacle (4), or from the battery through the electrical power control switch (8). When this switch is turned to BATTERY, power is furnished to the battery relay (7), and thence to activate the primary bus (6), the secondary bus relay (9), and the secondary bus (10). In this manner the primary and secondary buses become the power source for the gun-firing controls. When the external power source is connected to the external power receptacle of the aircraft, the short connector of the plug makes contact with its mate in the receptacle last, and closes the circuit with the external power relay (5). The short connector of the plug, in making contact last while being unplugged, eliminates the chances of the exposed contacts arcing. The contacts are thus prevented from eroding and there is less chance of a spark igniting vapors as previously mentioned.

When the external power relay (5) closes while the electric power control switch (8) is in the OFF position, power is supplied to the primary bus (6) alone. When this switch is turned from the OFF position to either BATTERY or GENERATOR-BATTERY position, power is supplied to the secondary bus (10) by closing of the secondary bus relay (9).

The primary bus carries all of the circuits which directly affect the electrical operation of the aircraft while starting, landing, or in flight. The secondary bus carries all of those circuits which are auxiliary in nature to flight operations. They are the radio, radar, and most of the armament circuits.

There are several elements in the modern aircraft which draw their power ahead of the armament power relay (30), although most derive their power after it has been fed through this relay. One of these is the

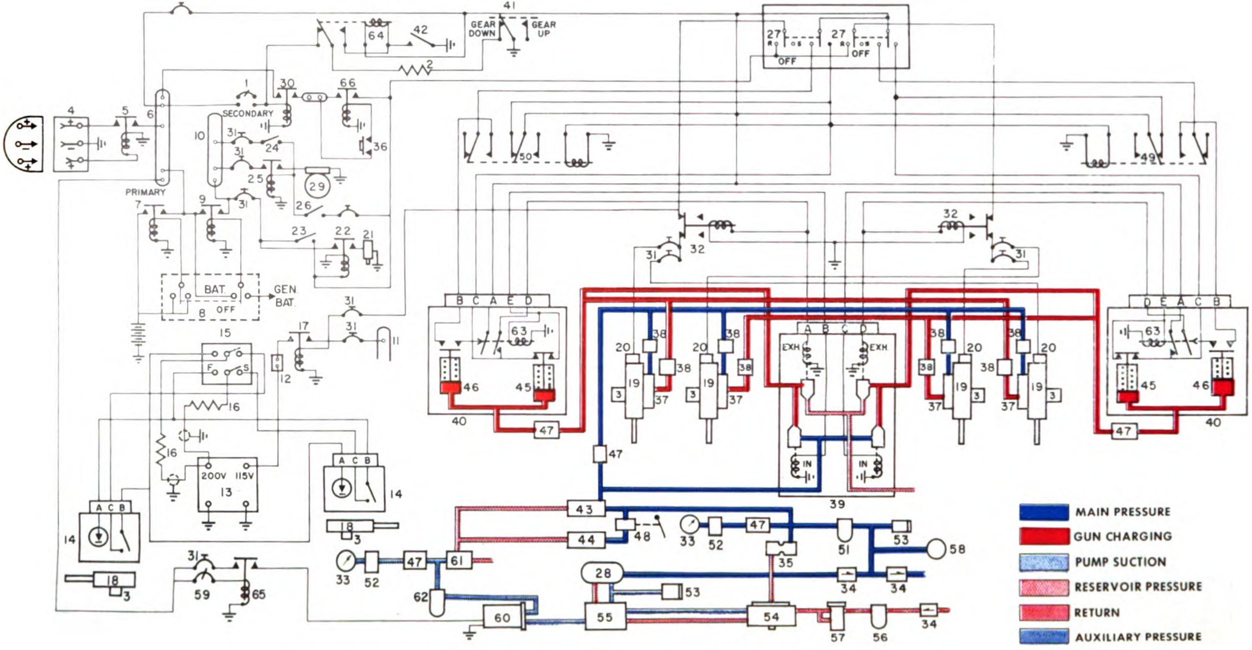


Figure 3—2.—Schematic diagram of hypothetical hydraulic gunfiring control and gun charging system.

Nomenclature for figure 3—2

1. Armament master switch.
2. Master switch safety resistor.
3. Gun feed mechanisms.
4. External power receptacles, 27.5-volt, d-c.
5. External power relay.
6. Primary bus.
7. Battery relay.
8. Electrical power control switch.
9. Secondary bus relay.
10. Secondary bus.
11. 115-volt bus.
12. Radio noise filter.
13. Transformer.
14. Synchronizing switches.
15. FREE-SYNCH switch.
16. Transformer resistor.
17. Gunfiring relay (115 volts).
18. Guns (electric primed ammo).
19. Outboard and inboard guns (percussion ammo).
20. Gunfiring solenoids.
21. Gun camera.
22. Gun camera relay.
23. Gun camera test switch.
24. Manual booster switch.
25. Booster relay.
26. Booster micro switch.
27. READY-OFF-SAFE switches.
28. Hydraulic pump.
29. Ammo booster (electrically driven).
30. Armament power relay.
31. Circuit breakers.
32. Gun charging firing control relays.
33. Pressure gage or warning light.
34. Pressure check valves.
35. Main system relief valve.
36. Gun trigger switch.
37. Gun chargers.
38. Quick disconnects.
39. Charger solenoid control valves (four-way valve).
40. Hydraulic gun (charger pressure regulator) charging pressure switches.
41. Landing gear handle relay.
42. Armament disabling switch.
43. Hydraulic combat manifold.
44. Hydraulic service manifold.
45. High pressure switch.
46. Low pressure switch.
47. Hydraulic fuzes.
48. Service manifold ON-OFF valve and lever.
49. Inboard gun selector relay.
50. Outboard gun selector relay.
51. Main system filter.
52. Snubber.
53. Ground hydraulic test connections (pressure and suction).
54. Upper reservoir.
55. Lower reservoir.
56. Reservoir pressurizing system filter.
57. Reservoir pressurizing system regulator.
58. Accumulator.
59. Auxiliary electric pump control switch.
60. Auxiliary electric hydraulic pump.
61. Auxiliary system relief valve.
62. Auxiliary filter.
63. Gun charging pressure switch control relay.
64. Gun safety relay.
65. Auxiliary electric hydraulic pump relay.
66. Gunfiring relay (28 volts).

gun camera (21). The testing circuit of the gun camera, actuated by the gun camera test switch (23), draws its power ahead of the armament power relay. It is necessary to test the operation of the gun camera relay (22) and the gun camera after loading at a time when the armament power relay is normally inactivated. Another element is the ammunition booster (29), which in certain installations, takes power ahead of the armament power relay. This is done so that the booster may function to aid loading the ammunition while the gunfiring and charging controls are deenergized. The gun chargers (37) also must be able to function while there is no current coming from the armament power relay. This is necessary so that the guns will be safetied (when necessary) without the armament circuit being activated when the aircraft is in operation. It is also necessary for the auxiliary electric hydraulic pump (60) to function while the aircraft is on the ground. The circuit for this pump is connected to the primary bus through a circuit breaker switch (59) which actuates the auxiliary electric hydraulic pump relay (65). One of the uses for this pump is to operate the hydraulic system for charging the guns while the aircraft is on the ground with the main hydraulic pump (28) inoperative.

The master armament switch (1) controls the power to the gunfiring controls of the aircraft through the armament power relay (30). A circuit breaker, which is an integral part of the master armament switch, is actuated by the functioning of the armament safety circuit. In the event of a malfunction in the electrical system of the master armament switch circuit, this circuit breaker automatically opens the switch and deenergizes the circuit. When the landing gear is lowered, and/or, as in some other installations, the tailhook is lowered, it actuates a micro switch at the tailhook or the landing gear handle relay (41). The actuation of this relay or micro switch grounds out the master armament switch circuit breaker, opening the circuit, and initiates the safetying of the guns and the gunfiring controls of the aircraft. The armament disabling switch (42) makes a momentary contact when placed in the DISABLE position to energize a holding circuit. This holding circuit deenergizes the armament safety circuit thereby allowing the gun system to be checked. The NORMAL position of this switch opens the switch contacts. A resistor (2) is placed in the line to the master armament switch to control the amount of current. This resistor protects the circuit breaker of the master armament switch by limiting the current that enters the switch during actuation of the master armament switch circuit breaker.

The armament power relay (30), when closed, controls the gun selector relays (49) and (50) and supplies power for firing the guns when the trigger switch (36) is depressed. Even if the trigger switch is depressed, thereby supplying power to the READY-OFF-SAFE switches (27), the guns will not fire IF these switches are in either the SAFE or OFF positions.

It will be remembered that in the pneumatic gun charging system, there was one READY-OFF-SAFE switch. (See (27), fig. 3–1.) However, in the hydraulic gun charging system, there are two READY-OFF-SAFE switches. (See (27), fig. 3–2.) In addition to the READY-OFF-SAFE switch in the pneumatic gun charging system, there are two selector switches—inboard and outboard. In the hydraulic gun charging system, these switches have been combined with separate READY-OFF-SAFE switches, so that instead of having three elements as in the pneumatic system, the hydraulic system has only two elements. It may be seen that the switching circuits of both the pneumatic and hydraulic gun charging systems serve identical purposes although they are not constructed alike. The two switches of the hydraulic system are placarded READY, OFF, and SAFE, but are called selector switches because they act as selector switches in setting up either the inboard or outboard guns, or both, for firing.

The selector switches of the hydraulic system when placed in the OFF position (gunfiring relay (17) and armament power relay NOT energized) will, in spite of being in the OFF position, initiate operation of the gun charging and/or safetying system indirectly. Current from the primary bus (6) passes through the inboard and outboard selector relays (49) and (50), back through the high pressure switch contacts (45), and from there to actuate the coils of the inlet solenoids of the four-way valve (39). These inlet solenoid valves are connected to the forward ends of the gun chargers by hydraulic lines. When the gun charging pressure switch control relays (63) are closed, a circuit from the primary bus is energized and forms a holding circuit which will remain in effect until the guns are fully charged and pressure for operation of the high pressure switches (45) is reached. The holding circuit previously described was actuated by a momentary switch. In this case a hydraulic switch is employed. At this time the high pressure switches open, and the holding circuit as well as the initiating circuit are deenergized. The guns will remain charged because the charging pressure from the main hydraulic pump (28) holds the gun chargers (37) in the SAFE position. Also the gun sears which are interconnected to the gunfiring solenoids (20) will hold the bolts in the SAFE position until released by action of the gun trigger switch (36).

With the selector switches in the SAFE position and the armament power relay (30) closed, power is supplied by the primary bus (6), through the selector switches (27), directly to the high pressure switches. With the gun bolts forward, the high pressure switches will close and the current will pass through them to close the pressure switch control relays (63) and open the inlet solenoids of the four-way valve. The inlet solenoid valves, when open, allow pressure to be exerted on the forward ends of the gun chargers. The pressure control relays will again form their holding circuits for the safetying portion of the charging cycle. When this portion of the cycle is complete, the high pressure switches will open the circuits and stop the action of the chargers. Hydraulic pressure and the action of the gun sears controlled by the gunfiring solenoids will hold the guns in the fully charged positions. In this position the guns are in a safe condition as previously shown.

When the selector switches are set to the READY position and the armament power relay closed, the selector switches allow the current supplied by the selector switches to pass through the inboard and outboard gun selector relays (49) and (50) to the low pressure switches (46) which are closed. From the current through these low pressure switches the exhaust solenoids and the inboard and outboard gun charging and firing control relays (32) are energized. In other words, the actuation of the gunfiring and charging control relays opens the firing circuit until the first half of the charging action is completed. This operation is performed by actuation of the exhaust solenoid valves which allow the main hydraulic pressure (acting at the rear of the gun chargers) to force the piston with its associated charging lug forward, thus completing the charging cycle.

As the pressure in the hydraulic lines to the forward ends of the chargers is exhausted and drops below 35–40 p.s.i., the circuit is opened by the low pressure switches' actuation. This actuation closes the exhaust solenoids and the gunfiring and charging control relays, returning them to their normal positions. In this condition, the guns will fire as soon as the gun charging and firing relay (32) is closed by the gun trigger switch. Firing action is brought about as the gun charging and firing relay furnishes power (through a set of contacts on each of the selector's switches) to the gunfiring charging control relay contacts. This power then flows through circuit breakers (31) in each circuit to the electrical gunfiring solenoids (20) which will then release the bolt sears. This allows the bolts to go forward, picking up their rounds of ammunition from the feed mechanisms (3), and firing the guns (19) as the bolts reach their battery positions and are locked.

There are many possible combinations of guns and gun systems. For purposes of illustration, the electrically primed ammunition 20-mm guns have been added to figure 3–2 to indicate how they operate and are connected into the circuitry of a gun system basically intended to make use of the percussion primed ammunition 20-mm guns. The electrically primed ammunition guns (18) receive their power from the 115-volt (a-c) bus (11) through a circuit breaker (31). From the circuit breaker the power goes to the gunfiring relay (17) through a noise filter (12), and from here to the transformer (13). This transformer converts the 115 volts to 330 volts d.c. which is used for the actual primer detonation. Each gun is wired from a separate 330-volt tap on the transformer, and each of these lines to the guns is routed through a transformer resistor (16) to the FREE-SYNCH switch (15). There are two positions on the FREE-SYNCH switch. The SYNCH position allows the guns to fire in full synchronization, or at the same time, usually by two's. In the FREE position the guns will fire freely, or individually as each one comes into its battery position.

During routine training flights, the guns of an aircraft are used very little when compared with the total time the aircraft is actually flown. If the percussion primed ammunition guns are allowed to remain in the charged position during the time that they are not used, the gun driving springs will become weakened enough to be unserviceable long before they normally should. In order to preclude this circumstance, the bolts should be allowed to go forward into the battery position until actual use of the guns is anticipated. In order to retain the gun bolts in the forward, or battery, position, the gun charger circuit breaker should be pulled to open the circuit while the bolts are in the forward position, thus deenergizing the charging circuit. In instances in which the guns are installed in the aircraft, but it is known that they are not to be used, they may be deenergized by disconnecting the two cannon plugs to the hydraulic pressure switches and applying tape or caps to seal the ends against fouling.

Hydraulic pressure which operates the gun chargers is supplied by the main aircraft hydraulic system through the hydraulic combat manifold (43). The main and auxiliary hydraulic systems of the aircraft are self-contained, air-pressurized systems and draw their fluid from the same reservoirs—the upper (54), and the lower (55). The pressurization for these systems is taken from the engine supplied air pressure which is used also to pressurize the pilot's cockpit. Air pressure to the cockpit pressurizing line is bled off and passed through a reservoir pressurizing system regulator (57) after passing through a pressure check valve (34) and a reservoir pressurizing system filter (56). The reservoir pressurizing system regulator reduces and regulates the 50 p.s.i. pressure. This regulated pressure is supplied to the upper reservoir during engine operation. The lower reservoir is interconnected to the upper reservoir by two lines, and the main hydraulic pump (28) driven by the engine draws its fluid from a standpipe in the lower reservoir. Thus, the main hydraulic pump cannot draw all the fluid from the lower reservoir. The remaining fluid may be used by the auxiliary electric hydraulic pump (60) to operate the combat and emergency components of the aircraft if and when needed.

The main hydraulic pump is a 7-cylinder axial type pump. It delivers nonpulsating flow with a constant displacement during each revolution. When pressure increases above the normal displacement of this pump per revolution, the displacement is automatically decreased until the pump is completely feathered, thus holding the pressure to the system's minimum requirements. A hydraulic check valve (34) is installed in the engine driven pump pressure line to prevent back pressures through the pump to the reservoir when an external hydraulic pressure power rig is connected for ground testing. An accumulator (58) is installed in the main pressure line to dampen out pressure surges within the system, and to serve as a storage point for a relatively small amount of hydraulic fluid to be used in the event that fluid is drawn from the system faster than the main pump can replace it. The main system filter (51) which is downstream from the accumulator prevents even microscopic particles from entering the system. From the main system filter the fluid is supplied to the main system relief valve (35) to the main pressure gage (33), through a hydraulic fuze (47), and from the main filter to the combat manifold (43). The fluid also flows through the service manifold ON-OFF valve (48) to the service manifold (44).

The main relief valve is a conventional spring-loaded poppet type unit. Its function is to maintain the main pump outlet pressure within safe limits. When excessive pressure occurs in the main system, this valve functions and returns the excess pressure through the return line to the upper reservoir. The hydraulic fuze is designed to pass a specific volume of fluid depending upon the volumetric demands of the system in which it is installed. If a failure occurs downstream from this fuze, and the total volumetric demand then exceeds that for which the fuze was designed, the fuze poppet will seat thereby shutting off the fluid with a minimum loss of the fluid contents of the system. The snubbers (52) function to protect the main and auxiliary pressure gages from pressure variations from all causes by restricting and limiting the fluid flow to them. Two passages with loosely fitting pins inserted (one in each passage) serve to restrict the sudden surges of pressure to protect the gage. Gradual changes in system pressure are not restricted by the snubber's action, and are registered on the gage.

The main system pressure gage registers the pressure supplied by the engine driven pump which is available for system operation. The main system filter is of micronic construction with a replaceable type element, is designed to be placed in the pressure line, and consists of a head assembly, filter element, and case. Spring-loaded valves are installed in the head assembly. The filter element is made of a specially treated cellulose, and has a capacity of 9 gallons flow per minute.

The service manifold ON-OFF valve and lever (48) function to control the main hydraulic pressure to the service manifold (44). The lever of this valve assembly is located in the cockpit, and the valve itself is located outside of the pressurized cockpit area with a mechanical linkage connecting the two elements. Before showing the functions of the two manifolds (service and combat), the auxiliary hydraulic system of the aircraft will be discussed. Power is supplied to the auxiliary electric hydraulic pump (60) from the primary bus (6) through a circuit breaker (31) to the auxiliary hydraulic pump relay (65). This relay is controlled by the auxiliary hydraulic electric pump control switch (59) which is located in the cockpit. The auxiliary hydraulic pump is a gear type continuous duty pump which delivers one-half gallon per minute at 1,500 p.s.i. The motor of this pump driven by the 27.5-volt aircraft current is equipped with pressure load bearings, and is so constructed that it is sealed and sparkproof. The auxiliary electric hydraulic pump may also be operated by actuation of the cockpit canopy ground control handle for actuating the cockpit canopy when necessary to open or close the cockpit while the aircraft is on the ground.

The auxiliary electric hydraulic pump should NOT be used for the same purposes for which the hydraulic ground test unit is normally used. It was not constructed for such purposes, and will give trouble if used to actuate hydraulic components of the aircraft to any extent during ground tests. However, if it is necessary to use the auxiliary pump during ground operation, a source of external power should be connected to the aircraft's external power receptacle to protect the battery and insure adequate power to the pump motor. The auxiliary hydraulic pump will perform its emergency functions even though the main hydraulic pump may have become inoperative or lost all of the fluid available to itself. The main pump has available all of the fluid in the upper reservoir plus the quantity in the lower reservoir above the end of the standpipe. Once this supply is exhausted, the main pump becomes inoperative. However, the auxiliary electric hydraulic pump may be energized to make use of the remaining fluid in the lower reservoir. Of course, the auxiliary pump may be used at any time desired as its supply of fluid is not limited by the standpipe, but it will normally be used only in time of emergency, or for limited operations on the ground as explained. Fluid is taken from the lowest point in the lower reservoir to feed the auxiliary pump, and this fluid is fed through a micronic filter (62) to a hydraulic fuze (47). From here the fluid is routed to the snubber (52) and the auxiliary pressure gage (33). Next downstream is the auxiliary system relief valve (61) past which the fluid moves on its way to the service and combat manifolds, (44) and (43).

The filter in the auxiliary system is the same type as the one in the main hydraulic system, but has a capacity of only 1.5 gallons per minute. The other units of the auxiliary system are the same as those of the main system. However, the auxiliary system pressure gage will not register pressure from the main system except when there is a malfunction of certain valves in the combat and service manifolds.

During normal operation of the main hydraulic system, the main hydraulic pump furnishes pressure to both the service and combat manifolds. However, the main hydraulic pump pressure may be cut off from the service manifold by the service manifold ON-OFF valve (48) at the discretion of the pilot. This action will cause the total pressure of the main hydraulic pump to be delivered to the combat manifold. If the main hydraulic system should be damaged, or for other reasons lose pressure, the auxiliary pump may be energized to supply pressure to both of the manifolds. The service manifold consists of a housing containing check valves, a thermal relief valve, and a series of check valves to prevent interflow between the units being served by the manifold. The units supplied by this service manifold will vary in different aircraft installations.

Spring-loaded check valves are installed throughout the service manifold to check back pressure to the engine driven and the auxiliary electric hydraulic pumps. Drilled passages in the housing of the manifold connect all outlet ports to a spring-loaded ball type thermal relief valve. Adjustment is provided for changing the spring tension on this valve. In addition to the above check valves, another series of check valves is located within the housing (one at each outlet port) to control fluid flow to the units connected to these ports. These check valves also prevent interflow between the systems connected to the manifold.

The combat manifold is a three-bank, check, and thermal relief manifold assembly. Pressure is supplied to this manifold from the engine driven pump and/or the auxiliary electrically driven pump. This manifold operates continuously.

Quick disconnects (38) are used throughout the aircraft's hydraulic system to connect and disconnect the various hydraulic units quickly with only a nominal loss of fluid and pressure. The two hydraulic test unit connections (53) shown in figure 3–2 are quick disconnects into which the external hydraulic test unit is connected.

Hydraulic fluid under system pressure is led from the combat manifold to the four-way hydraulic valve (39) in the gun charging system. Also, fluid from the same source is furnished to the feed tube (rear connection) of the gun chargers. The function of the gun chargers, pressure switches, and the four-way valve, have previously been discussed. However, a clearer understanding of the operation of these units may be gained through a more detailed description.

Hydraulic pressure entering the forward connections of the gun chargers (37) forces the charger pistons with their associated actuating shoulders (lugs), which engage the gun bolts, to recoil. This action charges the bolts to their rear positions. Hydraulic pressure is maintained on the gun chargers by the exhaust solenoid valves of the four-way valve (39) remaining closed. When pressure on the piston heads is relieved by the opening of the exhaust solenoid valves, the pistons are forced forward into their battery positions by fluid pressure from the inlet solenoid valves entering the chargers through their rear connections. While in these positions, the charging lugs of the pistons are clear of the bolts' operation.

The hydraulic gun charging pressure switches (40) each contain a low pressure switch (46), a high pressure switch (45), and a pressure switch control relay (63). The switches are operated by hydraulic plungers and controlled by adjustment springs. The normally closed low pressure switches are held open by the adjustment springs when the pressure is below the minimum setting of the adjustments. Hydraulic pressure acting on the low pressure plungers overcome the force of the adjustment springs and close the switch. When the pressure on the plungers drops, the adjustment springs open the switch. The low pressure switch is connected to the exhaust solenoid valves within the charger solenoid control valve (39) through a pair of normally closed contacts on the control relays (32). The normally open high pressure switches are held closed by the adjustment springs when the pressure reaches the minimum for the high pressure adjustments. Hydraulic pressure acting on the high pressure plungers overcomes the force of the adjustment springs and opens the contacts of the hydraulic switches. When the hydraulic pressure on the plungers drops, the adjustment springs close the contacts of the hydraulic switches. The high pressure switches are connected to the inlet solenoid valves of the charger solenoid control valve.

The control relays (63) each have a normally open and normally closed contact. The normally open contacts are connected to the primary bus (6). The normally closed contacts are connected to exhaust solenoids of the four-way valve through the low pressure switches (46). The control relays of the pressure switches are energized by the current from the primary bus passing through the high pressure hydraulic switches (45) to the pressure switch control relays. This current also simultaneously energizes the inlet solenoid valves of the four-way valve. The normally open contacts, which have current supplied to them by the primary bus at all times, while the aircraft is in operation, are used to form holding circuits.

The holding circuit operation is controlled by the high pressure switches. When the high pressure switches reach their maximum pressures, they open, removing the grounds of the holding circuits. The function of the holding circuits is to keep the gun bolts charging to the rear position by holding the inlet solenoid valves open, and the exhaust solenoid valves closed. It also functions to complete the charging cycle even though the switches are repositioned during the charging cycle. Thus, they are held closed until they are opened by the high pressure switches when the pressure preset on the high pressure switches has been reached. The bolts at this time will be in their extreme aft positions.

The charger solenoid control valve (39), or the four-way valve as it is frequently called, contains four solenoid operated control valves with plungers and poppets which operate against seats in the body so that when current actuates the solenoids, the poppets control the fluid flow inside the body. Detailed operation of the four-way valve may be found in the appropriate instructions. Basically, the four valves of this unit may be divided into two groups—the intake solenoid valves, and the exhaust solenoid valves. Fluid pressure from the main hydraulic system is furnished to the inlet solenoid valves. In operation these two valves control the gun charging pressure of the hydraulic system. The two exhaust solenoid valves hold the gun charging pressure of the system on the hydraulic gun chargers for safetying the guns when desired, and allow the gun charging pressure to be relieved, thus venting it through the return lines to the hydraulic reservoirs.

HYDRAULIC FLUIDS.—Any liquid which is not too thick might be used in an aircraft hydraulic system if incompressibility and fluidity were the only qualities desired. However, a satisfactory hydraulic fluid for aircraft use must possess a number of other properties. Severe operating conditions cause all oils to undergo unfavorable chemical changes. By severe operating conditions is meant operation for a considerable length of time under high temperatures. A "shearing" action may take place when oils, or fluids, must pass through small openings under great pressure, or between fast moving heavily loaded surfaces. These fluids may also "break down" if exposed to air, water, salt, or other impurities, especially if they are in constant motion or subjected to heat. These chemical and mechanical processes which break down the fluid result in the formation of sludges, gums and carbons, or other deposits. These deposits clog openings, cause valves and pistons to leak and stick, and in general cause a lack of proper lubrication to moving parts.

An ideal hydraulic fluid is free from acid and noncorrosive so that it does not adversely affect the metals with which it comes in contact. However, mineral base oils cannot remain completely noncorrosive under severe operating conditions. Certain chemicals, known as additives or inhibitors, are dissolved in oils to improve their characteristics. It has been found desirable to mix these chemicals with the oils only in specified cases in which severe operating conditions are known to exist, because addition of inhibitors has been shown to give satisfactory results for a limited time, then cause a more rapid deterioration of the oil than would have otherwise been the case. Opinion is still somewhat divided as to the merits of additives and inhibitors when combined with petroleum base fluids.

When motion takes place between surfaces in contact, friction tends to oppose the motion. Hydraulic fluid acts as a lubricant between the moving parts within the hydraulic system by reducing this friction to a minimum. Various liquids differ in their ability to lubricate and in their "film strength," which is the capacity of the liquid to resist being wiped out or squeezed out from between surfaces when spread to an extremely thin layer by pressure. Film strength in petroleum based hydraulic fluids is greatly enhanced by combining with it certain of the additive materials. The lubricating properties of a fluid derived from petroleum varies with the temperature, and other factors such as climatic and working conditions. Naturally, these conditions must be considered where the lubricating properties of a fluid are concerned.

The ability of a fluid to flow varies with the type of fluid concerned, other factors being equal. The thinner the fluid, the LESS the viscosity. Viscosity is the actual measurable resistance which a liquid offers to flow. Increases in temperatures cause decreases in viscosity of a fluid, as fluids always flow less easily when cold. A good hydraulic fluid must inherently form an excellent seal at pumps, valves, and pistons. However, it must not be so thick that it offers excessive resistance to flow, as this would inevitably lead to power losses and higher operating temperatures. At the other extreme, the fluid cannot be too thin as this would lead to unnecessarily rapid wear of moving parts and heavily loaded surfaces.

Foreign matter becoming mixed with hydraulic fluid is the major factor determining the useful life of the fluid. Contaminated fluid is not only useless, but damaging to the system. Fluid should not be exposed to the atmosphere longer than is actually essential, because dust and other foreign matter may easily contaminate it. Every hydraulic system incorporates numerous small orifices and close tolerances between the working surfaces of its components. Any contamination of the fluid by dirt, grit, lint, and dusts of all types constitutes a positive hazard to faithful operation of the system. Hydraulic filters placed in the system at strategic locations remove contaminants from the fluid. To illustrate how critical removal of all foreign matter becomes in modern hydraulic systems, these filters are designed to remove all particles in the fluid greater than $\frac{1}{5000}$-inch in diameter.

A new type of hydraulic fluid for use in main hydraulic systems of aircraft is currently replacing the oil base fluids. This new fluid is called HYDROLUBE, and is a water base material. Water is mixed with ethylene glycol in specified proportions to form the fluid. The viscosity of this new fluid remains most satisfactory throughout a wide temperature range, it is noninflammable, nontoxic, and possesses other admirable characteristics such as satisfactory lubrication and film strength properties. It is amber in color. Special and specific precautions and instructions have to be observed in replacing the oil base fluid in a system with the hydrolube fluid, as these two types of fluids do not mix without damage to, or failure of, the system. Hydrolube is not used in all hydraulic components of the aircraft. Landing gear struts, shimmy dampeners, and other components still require oil base fluids.

LUBRICATION AND PRESERVATION OF AIRCRAFT GUNS

In order for the Navy to maintain a high degree of logistic readiness, it is mandatory that a great many assemblies, subassemblies, and individual parts be produced, prepared for shipment, and transported to remote supply points. Practically every item produced by or for the Navy needs preservation of some type if not immediately put into service. The only method of keep-

g these items in good condition and free from corro-
on is through strict adherence to the preservation re-
iirements and methods of preservation set forth in
tail in the pertinent instructions and publications.

Aircraft guns, particularly, need preservation at all
mes when not in active service, as they are continu-
isly subjected to extremes in temperatures and to al-
ost constant exposure to salt air, rain, and other
urces of moisture condensation. However, before pres-
rvation is applied to any item, it is necessary for the
em to be thoroughly cleaned because of the fact that
ist, dirt, contaminated oils, and moisture cause rapid
eterioration of metal and metal surfaces. Handling of
eaned items should be done only with gloved hands, as
erspiration from the bare hands will cause acid stains
i the cleaned surfaces. Directly after thorough clean-
ig, the items should be preserved in accordance with
ie pertinent instructions. Following this procedure of
reserving the item directly after cleaning will insure
ie least possible chance for corrosion to get a start be-
re the preservative becomes effective. Although the
ecific instructions governing the preservation of all
pes of items are well established and should be fol-
wed to the letter, there are a few general instructions
iat pertain to applying preservation. These are:

1. Clean the part or item thoroughly.
2. Handle cleaned items with gloves.
3. Apply preservative immediately after cleaning, but only after item being preserved has reached room temperature and is completely dry.
4. Insure that ONLY the specified preservative is being applied.

The preserving, packaging, and packing performed by
e Navy may well be for periods of 5 years or more.
corrosive action which might have only begun to show
in from 2 to 6 months may have progressed to such
extent in 5 years as to render the preserved items
tally useless. The causes of corrosion may be divided
to two general classifications: direct chemical attack

of active gases, and electrochemical action. Practical experience has shown that corrosion due to direct chemical attack of active gases on metals is of relatively little importance IF corrosion due to electrochemical action is eliminated or prevented. This is due to the fact that the direct chemical attacks are also prevented in this case.

Practically all metals are affected by corrosive gases which exist in the atmosphere. However, if there is little or no free moisture in the atmosphere, the rate of attack is extremely slow. This is due to the fact that a thin film formed by the action of the corrosive gases serves as a protective layer which inhibits further attack on the base metal. Oxygen has been found to be one of the best protective agents for certain metals in spite of the fact that it will attack all types of metals to varying degrees. The original attack on the metal by oxygen produces a thin uniform layer of oxide which tends to prevent further attack by the other elements. A good example of this is the manner in which aluminum will last indefinitely in air. Oxygen forms a protective oxide layer over this metal almost immediately on its exposure to air. The metals found in aircraft guns react similarly, but to a much lesser degree. For the above type of thin oxide layer to form, it is necessary for there to be no free moisture in the atmosphere, as moisture hastens and abets all types of corrosion. When free moisture is present, the protective layer or oxide coating on metals will be changed into other oxides, hydroxides, chlorides, sulfates, and other equally corrosive elements, and they will destroy some of the base metal of the items. Naturally, the rate of destruction is proportional to the temperature, humidity, evaporation, and other effects.

Although electrochemical action is not of too great concern with respect to aircraft guns due to the fact that most of the various components of the gun are made from the same type metal, it is of interest to the ordnanceman, and its process in the corrosion of dissimilar metals should be understood. When two different metals are in electrical contact through moisture or other types of electrolytes, corrosion is apt to take place on one of the metals. Under the above conditions, if sufficient differential of potential exists, corrosion will occur with the more nearly electronegative metal (acting as the anode) receiving the corrosion. Two types of corrosion will result—surface type, or intergranular type. The intergranular, which is the more damaging of the two types, affects the molecular structure of the metal thereby causing weakness of the metal and internal destruction.

It has already been stated that electrochemical corrosive action is greatly hastened by moisture. However, even in the presence of relatively dry air (well below the saturation point), this action will occur. This is brought about by condensation and adsorption of water vapor by particles of hygroscopic matter (those particles which have an affinity for moisture) producing liquid films or spots on metal surfaces. For this reason it is absolutely necessary to eliminate all hygroscopic matter by thorough cleaning, and to maintain a relative humidity in which surface condensates will not form. If the metal part or item is to be sealed with desiccants (silica gel, etc.) placed within the sealed enclosure, corrosion may commence even before the desiccants are able to dry the air inside the enclosure. This is especially true if the item is not thoroughly cleaned of all hygroscopic matter and all residual moisture prior to being sealed. This is equally true of preservation processes of aircraft guns. If the guns are not carefully cleaned and dried prior to the application of the preservative, little practical advantage is afforded in the process, as corrosion is likely to take place under the preservative.

In order to standardize the methods by which articles subject to corrosion and deterioration are preserved, the Navy has instituted a system which divides all preservation processes into five basic methods. These are the Method O, packaging for mechanical protection; Method I, contact preservation; Method IA, waterproof packaging; METHOD IB, strippable compound coating; and METHOD II, dehydrated packaging.

In selecting any one of these methods over the others, a determination has to be made as to the nature of the material or equipment to be packaged and the degree of protection required. Once the selection has been made, the preservation and packaging instructions must be faithfully carried out in order for the desired results to be obtained. One poor seal in a moisture-vaporproof barrier, for instance, renders the entire package useless.

The materials used in preservation and packaging must conform to the specifications covering their manufacture and condition. Torn or excessively worn wrapping materials are absolutely worthless as barrier materials. Once the preservation process has been commenced, it should be performed as a continuous operation if at all possible. Any delay between the cleaning of the part or assembly and its final preservation or packaging provides an excellent opportunity for contamination. It has been shown that no preservative can protect a previously contaminated metal surface. Therefore, the gun or part has to be completely cleaned and dried prior to preservation. The contact preservatives will not prevent corrosion when moisture is trapped between the part and the protective coating. Thus, it is easily understood that proper cleaning and drying by stipulated methods are primary steps of all adequate preservation techniques.

Choice of the proper preservative and its correct application are highly important requirements for adequate protection of equipment during shipment and while in storage. When a particular type of preservative has been selected for use, consideration has to be given to the best type of packaging and wrapping to protect as completely as possible the preservative which has been applied. If the preservative used does not have good resistance to impact or abrasion, the wrapping and packaging has to be of the type designed to protect the preservative coating. In other words, the types of preservatives should be correlated with the type of packaging to be used in order to balance out the possible short-comings of each. If metal parts have been given surface treatment such as oxide coatings (Pentrate, Dulite, Ebonal), phosphate coatings (Parkerize, Parco-Lubrite), or sulfide coatings (Ferrotex), or platings of cadmium, tin, or zinc, the method of preservation to be used should be scrupulously selected from among those which are designed to PROTECT THE PARTICULAR METAL TREATMENT (finish) concerned.

Unless a requisition or a technical order has specifically called for the exact method of preservation, the method to be used must be dictated by the nature of the unit or equipment to be preserved. Details of construction, such as the unit size, shape and weight, type of material used in its construction, and ultimate usage, must be considered when selecting the proper method of preservation. There are numerous parts which have critical functioning surfaces. Even microscopic rust stains will often render these surfaces useless due to their inherently close working tolerances. This type of equipment deserves and requires that particular attention be given to its preservation procedure. It should always be borne in mind that improper preservatives will ruin parts and equipment.

The purpose of lubrication is to reduce friction between sliding or frictional surfaces and, to a degree, to protect the metal parts against corrosion. Aircraft guns require the correct lubrication for satisfactory operation at all working temperatures. Due to the extremes in temperature to which aircraft guns are exposed, highly specialized oils and greases are a necessity. One fighter pilot flying at altitude may have to fire his guns at a temperature of –60° F. Another pilot may have to fire his guns in support of a beachhead where the ambient temperature is around 110° F. It is quite possible that only one lubricant will be used on both sets of guns. For this reason it may easily be seen that this lubricant has to embody special characteristics. The Navy is not satisfied to rely completely on any one type of oil for lubrication of its guns and, as a result, endless research continues to produce lubricants which will have better and better characteristics. As aircraft are made to reach higher altitudes with each passing month, new lubricants have to be produced to keep pace with lower and lower temperatures.

A lubricant which would combine the best properties of a lubricant and a preservative would be of inestimable value to the services. Such a compound may even now be near realization, as research has produced a material which not only acts as a lubricant but also serves the purpose of a preservative. It is most interesting to note that this material reportedly needs no removal prior to firing the gun which it protects.

Lubrication of aircraft guns should be in strict accordance with the technical manuals published for the particular type of gun concerned. However, a few general rules apply to the lubrication and preservation of most guns. Aircraft guns should be cleaned and lubricated daily after firing, and after firing each 600 rounds when more rounds are to be fired the same day. Actually, they should be cleaned and lubricated more often when and where possible. The proper method of applying any lubricant is to saturate a clean cloth in the specified oil, wring it out completely by hand, and wipe all parts of the gun with this cloth. The oil should be applied sparingly enough so that only a thin film is left on all working parts. If it is seen that more than this amount of oil is left on the gun, a clean, dry, gritproof and lintproof cloth should be used to wipe all such parts. Failure to remove all but a thin coating of oil may possibly result in malfunction of the gun at extremely low temperatures. Excess oil in the bore of the gun when fired may raise the chamber and breech pressures to an extremely dangerous degree. The chamber and bore should be wiped completely dry before the gun is fired.

OILS, GREASES, LUBRICANTS, AND PRESERVATIVES.—The various materials used by the Navy for the lubrication and preservation of guns in aircraft are all classified and purchased under specifications and standards which are used in the manufacture of these materials. In order for a certain lubricant to do its appointed job perfectly and to be the same each time it is produced by any manufacturer, it has been found necessary and economical to set up detailed specifications and standards for the manufacture of this lubricant. The same is true of thousands of other materials, services, and products used by the Navy. When such a system of standardization was found to be expedient and necessary, the Navy was the first to set up the machinery to bring about complete standardization of the materials, products, and services it used.

In order to become familiar with the specifications and standards set up by the Navy, reference should be made to the GUIDE FOR SPECIFICATIONS, STANDARDS, AND QUALIFIED PRODUCTS LISTS issued by the Navy Standardization Board. There are various types of specifications, and each is assigned a precedence in use. The FEDERAL specification is the first to be used in the procurement of a material, product, or service for the Navy if one exists which is satisfactory for use. If a satisfactory Federal specification is not available, then a MILITARY specification will be used. If neither a Federal or a Military specification exists covering the material desired, a DEPARTMENTAL or bureau specification may be used.

Specifications are clear and accurate descriptions of technical requirements for a material, a product, or service. They include procedure for determining that the requirements have been met. Packaging and packing requirements are detailed to make certain that the materials will be fit to use when delivered. Specifications insure the Navy that the materials procured are precisely what has been ordered. They are referenced in, and become part of, contracts with commercial suppliers.

The use of specifications in procurement leads to economy by standardization. Repeated procurement based on a single specification for a single item lowers production costs for the manufacturer. Quantity purchasing of an item is made possible with the resultant decrease in price per item by the use of a single specification. Standardized maintenance of equipment procured under a single specification is insured to the Navy. And benefits from the use of specifications include reduced inventory and consequent savings in time, space, clerical help, labor, and money.

Ordnancemen, especially first class and chief petty officers, should be familiar with specifications as they are a great help in requesting just the right material needed. At times, the particular material needed may not be stocked locally, and by knowing how to use the various indexes of specifications, a suitable authorized substitute may be procured and safely used. Stock numbers should accompany the specification symbol as they are closely allied in procurement requests.

Materials used in the cleaning, lubricating, and preserving of aircraft guns will be described below. However, no attempt will be made to cover in detail all of these materials, as they may be found by referring to specific Bureau of Ordnance and Bureau of Aeronautics publications. Those detailed below are the ones in general use.

SPECIFICATION MIL–C–3372 (STOCK NO. GM6850–224–6658) LIQUID RIFLE BORE CLEANER. This is a general rifle bore cleaner. It is used to clean bores after firing, and prior to firing if the guns have remained idle for an appreciable time. As the base of this cleaner is water, the bores have to be thoroughly dried with successive dry patches, and an oily patch run through the bore afterwards to prevent corrosion.

SPECIFICATION MIL–C–11796 (STOCK NO. WM8030–285–1570) SOFT FILM CORROSION PREVENTIVE COMPOUND. This compound is used as a corrosion preventive on guns installed in aircraft. It is easily removed through hand cleaning with P–S–661 dry cleaning solvent. MIL–C–11796 is especially useful on guns which are to be stored for some period of time. Since it is relatively easy to remove this compound, it may be used by activities which do not have vapor degreasers. It may be applied by dipping, spraying, or brushing. However, it is mandatory to remove this compound before firing the gun. After the compound is removed, the gun should be lubricated with GLT–700–60 oil before firing. Guns preserved with MIL–C–11796 will have to be spot checked each six months to insure that adequate protection is being maintained.

SPECIFICATION MIL–C–16173 (STOCK NO. WF8030–224–9578) HARD FILM CORROSION PREVENTIVE COMPOUND. This hard film compound dries to a hard coating and is not easily removed. It is used when guns and gun parts are to be preserved for long time storage. Since it is hard to remove, MIL–C–16173 should not be used by activities which would have to remove it and which do not have degreasing equipment available. Prospective "RB" category material (old Class 265 overhaul) should be cleaned and coated with this compound prior to being released by the activity preserving the gear. This compound may be applied by brushing, spraying or dipping. It is necessary to spot check guns preserved with this compound only each 12 months to insure that adequate protection is being afforded.

It might be said here that, for the sake of economy, it is necessary to carefully preserve guns which are prospective "RB" category material. If reasonable care is exercised in the preservation of these guns going to overhaul, they will arrive at the overhaul activity in a highly satisfactory condition. Overhaul will then be possible and justified; whereas, if these guns are poorly cleaned, preserved, and packaged, it is likely that by the time the overhaul activity can schedule them, they will be so badly corroded that overhaul will not be economically justifiable.

SPECIFICATION MIL–G–4343 (STOCK NO. WS9150–269–8255) PNEUMATIC SYSTEM LUBRICATING GREASE. The seals, gaskets, and washers of pneumatic systems need lubrication. This grease is especially manufactured to lubricate such components without causing their deterioration. Pneumatic chargers and pneumatic feed mechanisms need this grease for proper lubrication.

SPECIFICATION MIL–G–15793 (STOCK NO. WS9150-235–5540) LOW TEMPERATURE GREASE. This grease has many applications on metal frictional surfaces which are exposed to extremely low temperatures. Aircraft guns naturally fall into this category. This grease may, therefore, be used on all frictional surfaces of aircraft guns upon which a grease may be used in place of an oil.

SPECIFICATION MIL–L–644 (STOCK NO. WM9150–231-6689) SPECIAL PRESERVATIVE LUBRICATING OIL. This oil is basically a lubricant and not a preservative. As a matter of fact, it affords little protection as a preservative. Guns installed in aircraft that are ready for combat shall be lubricated with this oil. MIL–L–644 oil should not be diluted with kerosene in anticipation of cold weather operations as it has been found that dilution does not help in extremely cold temperatures, and is definitely detrimental to operation at temperatures above –20° F. This oil does contain a rust inhibitor, but it affords only a limited protection. MIL–L–644 has a high evaporation rate, and consequently requires frequent reapplication.

NRL LUBRICANT SPECIFICATION GLT–700–60 (STOCK NO. J941–L–4025). This grease is a semifluid, synthetic mixture developed by the Naval Research Laboratory for the Mk 12 20-mm aircraft gun and the Mk 7 and Mk 8 feed mechanisms. It may also be used on the Mk 3 and the Mk 16 aircraft guns when MIL–L–17353(ORD) lubricant is not available. Specification GLT–700–60 lubricant is not compatible with O-rings and T-rings fabricated from other than MIL–P–5516 specification rubber. Therefore, these rings have to be changed to those made of MIL–P–5516 rubber prior to application of the grease.

Unlike other greases and oils, GLT–700–60 does not cause damages to the guns if, in lubricating the ammunition, too much is applied. This grease may be used on all parts of the aircraft guns where lubrication is indicated except the recoil springs. These springs are prepacked with a specialized graphite compound and do not require relubrication. Some of the advantages to be found in using Specification GLT–700–60 lubricant are that it resists icing, lubricates well down to –65° F., adheres closely to vertical surfaces, does not evaporate completely when subjected to a high-speed airstream at elevated temperatures, resists emulsification with water, inhibits rust, and does not require frequent reapplication. SPECIFICATION GLT–700–60 IS TAKING THE PLACE OF BOTH SPECIFICATION MIL–L–644 AND MIL–G–4343 LUBRICANTS FOR USE IN AIRCRAFT GUNS.

SPECIFICATION MIL–L–3150 (STOCK NO. WS9150–231–2361) MEDIUM PRESERVATIVE LUBRICATING OIL. Guns preserved with this oil are protected against corrosion for a greater length of time than with MIL–L–644. Guns installed in aircraft which are not in combat readiness may be coated with this oil. However, guns coated with MIL–L–3150 must be inspected each 20 days when the aircraft is stored inside, and each 7 days for those not hangared. Adverse weather conditions will materially reduce the periods between spot checks. It is important to note that MIL–L–3150 is not a satisfactory lubricant, and must be removed with oil before the gun is fired.

SPECIFICATION MIL–L–17353 (STOCK NO. J941–0–50) SPECIAL LOW TEMPERATURE LUBRICATING OIL. This oil, familiarly known as "E–51," may also be used on aircraft guns where a good low-temperature lubricant is needed. It is probably used more than any other oil for this purpose. It shows satisfactory performance in temperatures as low as –70° F. When "E–51" is used on the Mk 12 aircraft gun and others, care must be exercised not to permit this lubricant to come in contact with the O-rings and the dielectric materials of the gun's firing circuit. To do so will destroy these materials.

SPECIFICATION S75–G (STOCK NO. J941–C–5000) WA-

TER REPELLENT COMPOSITION. This repellent is used on the actuating spring (drive spring) of certain feed mechanisms, and other places not easily accessible for regreasing.

SPECIFICATION P–S–661 (STOCK NO. WF6850–264–9038) DRY CLEANING SOLVENT. The P–S–661 solvent is used in a great many places about the aircraft. It is an excellent degreasing agent and is safe to use on most all aircraft surfaces. It is especially useful for removing oil, grease, and compounds from the interior and exterior of aircraft guns. It may even be used on aircraft skin surfaces as a cleaner and on many components of the aircraft.

GUN INSTALLATION PROBLEMS

Within the experience of any first class or chief ordnanceman there will be many instances in which installation problems have occurred with regard to aircraft guns. Problems will arise with the feed mechanisms, chuting, link and case ejection, installation troubles with the guns themselves, and troubles from many other sources. As a rule, installation troubles and problems are the business of the manufacturer and the major overhaul activities. Theirs is the basic responsibility to insure that gun systems are properly installed in the individual aircraft, and to see to it that they operate according to design specifications. However, in spite of all the thought, planning, designing, and care in manufacture, there are inevitably problems that arise during service use of the equipment. It is quite likely that the ordnanceman will be called on to aid in the remedial action afforded such instances.

FEED DIFFICULTIES.—Generally speaking, most gun systems will be in need of adjustments to the feed mechanism, the boosters, and the chuting at the time the aircraft are procured by an activity. These adjustments are usually minor in nature unless some of the component parts of the system have been distorted or misaligned in shipment. Service use of the aircraft will cause more troubles with the feed system, and these troubles usually have to be taken care of on the squadron level. For this reason, the ordnanceman has to become familiar with the type, nature, and effective elimination of such troubles.

Unless all integral parts of the gun feed are operating as they should, jams will most likely result. The chuting has to be smoothly led from the ammunition cans to the guns with no sharp bends and no distortion of the chuting itself. The boosters, if such are used, have to be in perfect working order, be securely fastened and secured to the chuting, and the incorporated micro switches carefully adjusted to feed the ammunition at precisely the right time. The feed mechanisms have to be in proper working order and correctly lubricated. The ammunition has to be properly calibrated while being belted, and correctly lubricated. If the ammunition is prebelted, the splicing round has to be calibrated with the rest of the rounds each time the belt is cut or spliced. This is necessary in order not to have a jam when this section reaches the gun and booster, or in the chuting before this section reaches the gun. Uncalibrated ammunition will quite often bind as it leaves the ammunition cans. At times, even though the ammunition is fed into the cans as shown in the instructions, violent maneuvers of the aircraft will upset the orderly flow of the ammunition from the cans. This causes it to bind and tangle within the cans. Naturally, this will cause a jam until cleared.

LINK AND CASE EJECTION.—Early installations of gun systems in aircraft usually made no provision for saving the spent cases (brass) and the links resulting from firing. These pieces were simply dumped overboard through various types of chutes. In recent years it has been made a practice to save the brass and links. There were several reasons for the adoption of this latter procedure. It resulted in a good saving of strategic materials. It also lessened the change to the critical center of gravity of the aircraft during flight by retaining a good portion of the original weight of the ammunition aboard. Also, by examining the spent cartridges and the links, the ordnanceman can quite often determine how the guns have been firing and whether or not there have been certain recognizable difficulties with the feed and gun mechanism. If there were a number of live rounds in the spent case compartment, it may be reasoned that a malfunction of the gun or guns had occurred which necessitated frequent charging of the guns by the pilot. The brass and links are usually trapped in the nose of fixed gun installations, where they serve as ballast.

AMMUNITION CHUTING.—It has always been a problem to get the ammunition to move from its cans to guns without binding or giving other troubles. The cans have been relocated many times, and chuting has been rearranged as many times, all in an effort to improve the situation. Boosters have done a lot to help in this matter as they help pull the ammunition from the cans even during maneuvers. Due to this action, the guns do not have to work as hard to get the ammunition into the feed mechanisms and breeches.

Some of the major difficulties with chuting stem from spot welds breaking loose; loosened or fatigued spring steel clips which join the chutes to the guns, cans, and boosters; uncalibrated ammunition hanging up in the chutes; links jamming in the chutes; and in clearing the jammed links and spent rounds from the chuting. It is very important to lead the chuting from the cans, through the boosters (if used), to the guns, in a smooth uninterrupted curve. Once they become dislodged from this smooth curve, feed troubles will result.

GUN AND CAMERA MOUNTS.—The present trend in mounting guns is to place them as closely adjacent to one another as possible. This results in a more or less crowded condition in the gun compartment. The ordnancemen have to work out the best and most efficient methods of changing guns in each type of installation as they will all be different. After working with one type for a while, shortcuts may be found that will materially hasten the job of removing and installing the guns. These gun mounts actually give little trouble outside of an occasional binding of the securing latches which makes installation and removal of the guns difficult.

Gun camera mounts come in so many design types that there is no need to discuss them all. As a general rule, these mounts give very little trouble, and the ordnanceman can assure that they will work properly by performing a nominal amount of preventive maintenance on them from time to time. This maintenance should consist of occasional lubrication of the hinged type, and checking of the locking features which secure the elevation and azimuth adjustments.

SAFETY PRECAUTIONS

The best safety precaution to be observed when involved in work on gun systems is to know and understand the operation and function of the electrical, pneumatic, hydraulic, and mechanical components of the system. This knowledge has not always been gained by the ordnanceman due to lack of experience with the particular system concerned. There will undoubtedly be a period of time in which practical experience and knowledge of the system will have to be gained before he becomes proficient with the system. It is during this period of time that the ordnanceman should proceed with the greatest caution. The length of this period will depend on the individual's ability to mentally absorb the necessary instructional media and to become skilled in the actual work on the system. After only a short indoctrination, the ordnanceman will find for himself that safety precautions are greatly needed and should be learned point by point.

Some of the more pertinent safety precautions concerning gun systems follow:

1. Precautions, such as those promulgated by ComNav-

AirLant, ComNavAirPac, BuOrd, BuAer, and others, should be published for all hands. Draw up and publish safety precautions for the equipment being used by the activity. Require all hands to read and initial all such safety precautions published at least once each four to six months.

2. CONSIDER THAT ALL GUNS ARE ALWAYS LOADED, and proceed with this in mind until personally assured that they are not loaded.

3. Personnel who are required to close the trigger switch during testing shall visually check all gun chambers before testing the firing circuit or letting the bolts go to their battery positions.

4. Misfires shall be treated as instructed in the latest directives.

5. Check four-way valves and pressure switches (where installed) for sluggish or improper operation.

6. Use only the authorized testing equipment when testing electrical circuits.

7. Use all of the recommended safety devices when testing electrical circuits.

8. When working on equipment employing high pressure air, use all recommended precautions for protection of eyes, and follow the instructions covering the sequence of steps required in the work.

9. When doing work on high pressure hydraulic systems, be particularly careful to vent the pressure prior to removal of a component of the system, or performing other work on the system.

10. In clearing jams in the guns, protect the fingers by securing the bolts in the aft position so that they may not accidentally return to battery.

11. Check all gun bores for obstructions before loading their feed mechanisms.

12. All fuzed ammunition has to be handled in accordance with the latest directives.

13. When clearing a jammed gun, be entirely sure that the muzzle is pointed in the safest possible direction.

14. When loading guns on the line, make sure that the

ircraft's guns are pointed away from all obstructions nd populated areas.

15. Use only the specially tipped section of the cleanng rod for clearing ammunition which has become ammed in the chamber.

16. Periodically clean out the blast tubes of all guns o that no residue from the products of combustion of he powder may build up on the inside surfaces.

17. If in doubt concerning the safe operation of a gun r the gun system, seek and obtain competent aid prior o doing the work yourself.

18. The safety devices WILL BE USED. Do not bypass hem or render them inoperative.

19. Keep a running check of the condition and usage f all guns, paying particular attention to sources of ncipient failures as noted by the Bureau of Ordnance, he Bureau of Aeronautics Representative, and other ources of published information.

20. Keep gun and feed mechanism logs up to date.

21. Visually check the feed mechanisms for security, lignment, and operation.

22. Investigate and eliminate any difficulties in elecrical circuits which have been the cause of circuit breakrs opening during operation of the system.

23. In transporting long sections of belted ammunition se the proper conveyance, thereby lessening the chances f uncalibrating the rounds through rough handling.

QUIZ

1. Gun charging systems in aircraft are hydraulic,
    - a. electric, and manual
    - b. electric, and pneumatic
    - c. and pneumatic
    - d. pneumatic, electric, and manual

2. While on the ground, the power supply to the aircraft's gun charging system should be derived from
    - a. the aircraft's battery
    - b. the aircraft's generator
    - c. the aircraft's battery or generator
    - d. an external source

3. The amount of current at the armament switch during safet circuit operation is controlled by
    - a. an armament relay
    - b. a battery
    - c. a resistor in the master armament line
    - d. all of the above

4. Ammunition gun boosters are controlled by
    - a. the charging system
    - b. a system of mechanical linkages
    - c. micro switches or clutches
    - d. the gun

5. The FREE-SYNCH switch will operate the guns
    - a. when the port gun is shorted out
    - b. when the starboard gun is shorted out
    - c. in free or synchronized fire
    - d. in all of the above

6. The gun camera is actuated by what number of circuits?
    - a. One
    - b. Two
    - c. Three
    - d. Four

7. The reason for bypassing of the master armament switch b the gun camera circuit is to
    - a. provide an auxiliary circuit in case of shorts
    - b. permit the use of the camera without energizing the arm ment circuits
    - c. permit the use of the camera with guns only
    - d. permit the use of the camera with guns, rockets, a bombs

8. No attempt should be made to work on high pressure air systems without first
   a. removing air connections
   b. removing power connections
   c. bleeding off all pressure
   d. turning off the compressor

9. The number of compression stages in the piston type air compressors used in aircraft pneumatic systems is
   a. one
   b. two
   c. three
   d. four

10. For the compressor of an aircraft's pneumatic system to operate at maximum efficiency the
   a. compressor must run for six minutes
   b. bottles must be topped off from an external source before flight
   c. compressor must run three minutes
   d. temperature must be above 70 degrees

11. A double-acting pneumatic charger is operated by air pressure
   a. in both directions
   b. on the charging stroke only
   c. on the return stroke only
   d. on the charging stroke and by spring power on the return stroke

12. Armament safety switches are incorporated in
   a. landing gear only
   b. tailhook only
   c. tailhook and landing gear systems
   d. none of the above

13. On hydraulic gun charging systems the four-way valves are controlled
   a. electrically
   b. by high and low air pressures
   c. electrically and by high and low pressures
   d. low pressure only

14. Aircraft air compressors are preset to a maximum working pressure of
   a. 1,000 p.s.i.
   b. 1,500 p.s.i.
   c. 2,500 p.s.i.
   d. 3,000 p.s.i.

15. Aircraft air compressors must have an oil change after how many hours of operation?
    a. 30
    b. 60
    c. 90
    d. 120

16. The transformer used in electrically fired ammunition circuits (electric primed ammunition guns) receives 115 volts a.c. and changes it to
    a. 200 volts a.c.
    b. 250 volts a.c.
    c. 300 volts d.c.
    d. 330 volts d.c.

17. The auxiliary electric hydraulic pump may be operated
    a. at any time it is needed
    b. in emergencies only
    c. for ground checks only
    d. for ordnance checks only

18. Hydraulic fluids must have the quality of operating under high temperature for
    a. short periods of time
    b. long periods of time
    c. at least 30 minutes
    d. at least 60 minutes

19. Hydraulic fluids will break down if exposed to
    a. salt water
    b. fresh water
    c. air
    d. any of the above

20. A hydraulic fluid that is too thin will cause
    a. rapid wear of parts
    b. hydraulic leaks
    c. loss of pressure
    d. none of the above

21. The latest type of hydraulic fluid has a
    a. water base
    b. mineral oil base
    c. alcohol base
    d. petroleum oil base

22. Hydrolube and hydraulic fluid may be mixed
    a. at any time
    b. under no circumstances
    c. in designated systems
    d. under close supervision

23. Hydrolube may be used in
    a. gun charging systems
    b. landing gear struts
    c. shimmy dampers
    d. all of the above

24. Electrochemical corrosion between two dissimilar metals is called electrolysis. It takes place more rapidly in
    a. hot dry climates
    b. cold climates
    c. fresh water
    d. salt water

25. Guns being prepared for long term storage must be
    a. carefully cleaned and dried before preserving
    b. oiled before being preserved
    c. washed with kerosene before preserving
    d. coated with vasoline before being preserved

26. For packaging and preserving items against corrosion and deterioration, the Navy has how many basic methods?
    a. One
    b. Two
    c. Four
    d. Five

27. Cleaning solvent P–S–661 is used on
    a. guns only
    b. all parts of the aircraft
    c. some components of the aircraft as well as the guns
    d. all of the above

28. When preservative MIL–C–16173 is used on guns they should be checked every
    a. 30 days
    b. 90 days
    c. 6 months
    d. 12 months

CHAPTER 4

AIRCRAFT BORESIGHTING

THEORY OF BORESIGHTING

The purpose of boresighting aircraft armament is to establish a relationship between the flight attitude of the aircraft, the bore axis of the armament, and the axis along which the sighting is projected. The theory of boresighting involves analyzing pertinent ballistics and mechanical data in establishing the relationship between the sight line of the aiming device (sight) and the trajectory of the missiles being fired or launched in order to predict the mean point of impact of the missiles at predetermined ranges. As no sighting device can do its job accurately unless it is properly aligned with the armament with which it is used, the sight and armament must be made to work together. The technique of making them work together is called BORESIGHTING.

Aircraft guns are boresighted so that their axis of fire either CONVERGE or remain PARALLEL throughout the trajectory. There are tactical advantages to be gained in both of these boresight methods, depending on the set of conditions existing at the time. When the guns are boresighted to converge at some point along the axis, a more concentrated fire will exist at this point, thereby producing a more deadly fire when the target is at the point of convergence. On the other hand, when the guns are boresighted so that they are parallel to each other, their concentration will be the same throughout the entire range of the guns. In other words, at any point within the maximum effective range of the guns the "lethal density" of the concentration will be the same.

There has been a trend in recent years to move the guns from their former positions within the wings to locations nearer the longitudinal axis of the aircraft, usually in the wing roots or the nose. Generally speaking, for installations in which the guns are mounted in the nose, parallel boresighting is performed. However, the final decision as to how they are to be boresighted is controlled to a great extent by their intended tactical employment, and by the needs and desires of the operating activity employing them.

Boresighting Terminology

For the sake of clarity and convenience in studying the pages that follow, the terms used in connection with boresighting are defined below:

ARMAMENT BORESIGHT DATUM LINE.—A horizontal line established on or within the aircraft by the manufacturer, having a fixed relationship to the flight path of the aircraft.

SIGHT AXIS—A straight line from the pilot's eye through the pipper (reflected sight image) which extends out into space.

BORE AXIS.—A straight line through the bore of the gun (from chamber through muzzle) which extends out into space.

BORESIGHT BRACKETS (POSTS AND RINGS).—Boresighting fittings which, when installed on the aircraft, establish a sight line on or parallel to the armament datum line of the aircraft. They are also called RODS and TEES. These brackets are either swung out from their stowed position within the aircraft or fitted in the aircraft at specified positions externally.

FLIGHT ATTITUDE.—The position of the aircraft while airborne in normal unaccelerated flight. Normal flight is the condition that exists when the aircraft is in level flight, is at its critical altitude, is flying at *V* max (average combat speed), is under full military power, and has a full military load less one-half the total fuel capacity aboard.

POINT OF CONVERGENCE.—The point at which the projectiles from all guns meet, or converge. Also the point at which the sight line and the bore lines meet.

DISPERSION.—The spread of gunfire or projectiles from each gun due to muzzle whip and other ballistic factors.

CENTER LINE.—The vertical line through the center of the aircraft which is perpendicular to the boresight line.

DATUM POINT.—A definite point on the boresight datum line where the line of sight through the boresight brackets will bear when the aircraft is properly aligned with the boresight screen or target. Its position with regard to the center line is given in the *Handbook of Maintenance Instructions.*

LETHAL DENSITY.—The concentration of gunfire or projectile impact density within a given area.

MEAN POINT IMPACT (M.P.I.).—The average point of gunfire (projectile impact) from an individual gun in which most density is registered.

LEVELING LUGS.—Lugs or blocks built into the aircraft by the manufacturer, designed to be used with a spirit level or quadrant when leveling the aircraft for boresighting.

FLIGHT LINE.—The line along which the aircraft is moving with respect to the air.

ZERO SIGHT LINE.—The sight line THROUGH THE PIPPER of a gunsight with fixed reflector, or through the pipper of an adjustable sight with the reflector set at zero. Gunsights are normally boresighted so that the zero sight line is parallel to the boresight datum line.

LINE OF SIGHT.—The line from the pilot's eye through the pipper of the sight (for a zero sight angle) to the hitting point.

TRAJECTORY (BULLET) DROP.—The angle between the line of sight to the hitting point, and the tangent to the trajectory at the instant of firing or release, disregarding parallax. Trajectory drop results from the force of gravity acting on the projectile.

SIGHT ANGLE.—The angle between the zero sight line and the line of sight to the hitting point at the instant of firing or release. It is considered positive when it is above (beyond) the hitting point, and negative when the pipper is below (short of) the hitting point. The main factors which determine the sight angle are trajectory drop and angle of attack. With a relatively small trajectory drop and a negative angle of attack, the sight angle may be negative. This often occurs when strafing and firing rockets. However, in bombing, the trajectory drop is so large that negative angles do not occur.

PARALLAX.—The apparent displacement of the position of an object caused by a shift in the point of observation.

ALLOWANCE FOR PARALLAX.—A correction to the sight made by adjusting the mount to change the sight angle to compensate for the fact that the sight is above the gun, rocket launcher, or bomb station.

GUN BORE LINE.—The center line of the gun bore. This line is established by the elements of the boresighting equipment.

POINT BORESIGHT.—The point on the zero sight line to which the guns are boresighted. This type boresighting is covered by instructions provided in the *Handbook of Maintenance Instructions* for the aircraft type involved.

LAUNCHER LINE.—The longitudinal axis of the rocket while fixed in the rocket launcher.

MIL.—An angle whose tangent is $1/1000$, or an angle of 1 mil subtends 1 inch at a distance of 1,000 inches. Naturally, it will subtend smaller lengths at shorter distances.

MEAN CHORD.—An arbitrary datum line from which the ordinates and angles of an airfoil are measured. It is usually a straight line tangent to the lower surface of the wing at two points, the straight line joining the ends of the mean line, which is the straight line between the leading and trailing edges of the wing.

TARGET SCREEN.—A fixture having separate aiming points for sight, individual guns, camera, and boresight brackets. It may be designed for use at any given distance in front of the aircraft. These screens are often painted on hangar doors, hangar bulkheads, or bulkheads aboard a carrier. They are normally designed for use at distances of from 10 to 50 yards.

TEMPLET.—Usually a covered steel frame containing aiming points for guns and gunsight. It is constructed so that it may be fastened to some part of the aircraft having a fixed relationship to the guns and gunsight. The guns and sight are then boresighted so that the sight and bore axes bear on the aiming points. However, due to the extreme care with which the aiming points have to be plotted, and the accuracy with which the templets have to be mounted on the aircraft to avoid large boresighting errors, it has rapidly lost favor. IT SHOULD ONLY BE USED WHEN NO OTHER METHOD IS AVAILABLE.

PARALLEL BORESIGHTING.—Alignment of all the armament of an aircraft and its gunsight so that the bore axes and the line of sight are parallel; parallax not considered.

CONVERGENCE BORESIGHTING.—Alignment of all armament of an aircraft and its gunsight so that the bore axes and the line of sight converge at some predetermined range or ranges; parallax not considered.

Parallel Boresighting

This method of boresighting is sometimes called INFINITY BORESIGHTING. Normally, in boresighting the guns of an aircraft parallel, the target prepared for the particular aircraft being boresighted is erected at 300 yards. There is much less chance of error in boresighting if the target is placed at this distance rather than at the extremely short ranges used aboard ship. Parallel boresighting produces a highly effective lethal density of gunfire along the entire trajectory up to the maximum effective range of the guns. This is especially true of installations in which all guns are closely grouped, such as those in the nose of our fighters.

Convergence Boresighting

For such tactical employment as ground strafing, it may be more effective to boresight the guns to converge at some point in the range, thus giving more spread of gunfire at points in front of the point of convergence. In convergence boresighting, all guns are aligned to fire to a certain point along the sight axis. This may be 300 yards, 500 yards, or whatever distance is set up by doctrine. The lethal density at this point in the trajectory is greatly magnified.

Each individual gun has its own dispersion due to muzzle whip or jump. This jump or whip is due to several factors—among which are the lack of rigidity of the long barrel, lack of rigidity of the gun mounts, the fact that the barrel tends to elevate itself when the gun fires, etc. In the guns that are boresighted parallel, the total dispersion from all guns will be greater than from those which are boresighted to converge to a point. Since this is the case, the effects of dispersion will be noted less in the guns which are boresighted to converge. Also, if one of the guns is not in proper boresight, the loss of its effectiveness will not be so noticeable when all guns are boresighted to converge as would be the case when all guns are boresighted parallel.

EQUIPMENT USED

Boresight Kit Mk 1

The Mk 1 aircraft boresight kit is a time-tested device for providing a convenient and accurate means of sighting along the bore axis of aircraft guns while boresighting. Sighting with this device may be done either from the breech or the muzzle by using the proper combinations of the units furnished with the kit. (See fig. 4–1.) For the sake of descriptive convenience, these units are divided into three groups as follows:

GROUP 1.
- Breechsight
- Cal. .30 adapter
- Cal. .50 adapter
- 20-mm breech adapter

GROUP 2.
- Muzzle sight
- Cal. .50 muzzle adapter
- 20-mm muzzle adapter
- Wrench

GROUP 3.
- Angular extension
- Eyepiece
- Straight extension

In group 1, the breechsight, when used with any of the three breech adapters, forms a simple telescope of four-power magnification. The telescope has no cross hairs, and the adapter is not self-aligning. The reasons for this will be discussed later. In group 2, the muzzle sight is a simple telescope of four-power magnification with a cross hair reticle. The muzzle adapters which align the axis of the muzzle sight with the axis of the bore are made of cast brass. Group 3 consists of four unit-power telescopes which are used to bring the point of viewing out to a more convenient position for sighting. The apparent angular field of these telescopes is rather small regardless of the assembled combination used, and is in the neighborhood of 33 mils, or about 2 degrees.

Installation of the Mk 1 boresight into the guns of an aircraft should not be attempted until definite consideration has been given to the method of boresighting to be used. In boresighting some configurations in which the guns are in the wings, the muzzles may not be accessible, thereby necessitating boresighting from the breech. In other configurations it may be necessary to boresight from the muzzles. Although it is advantageous for the sighting system to be as short as possible, it is

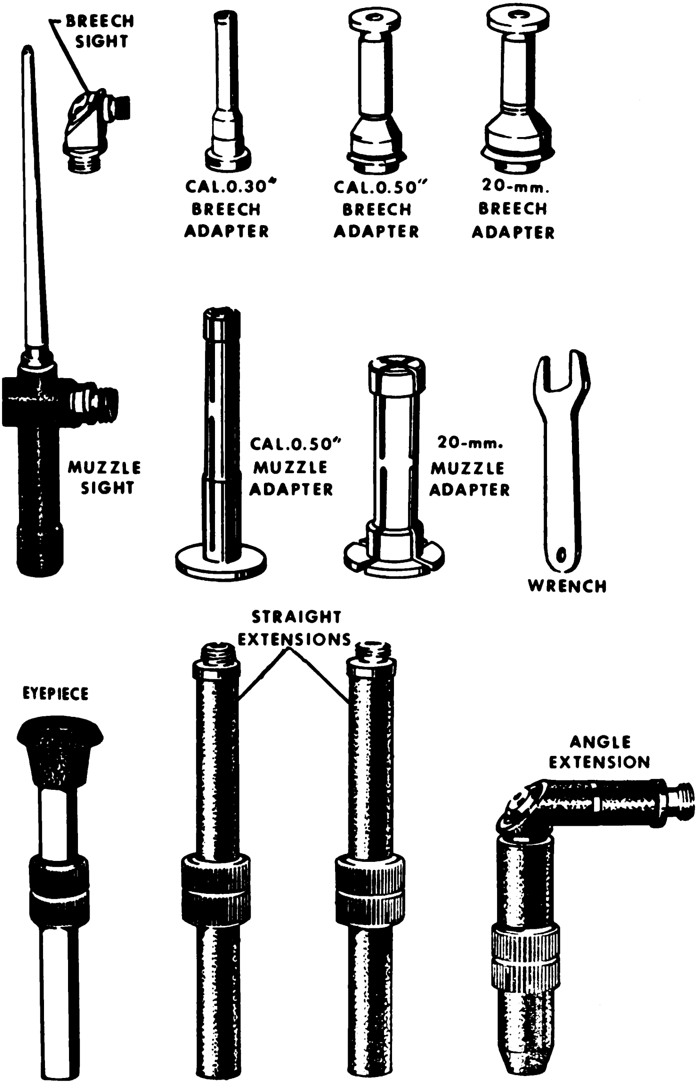


Figure 4—1.—Components of the Mk 1 boresight kit.

recommended that one straight extension and an angular extension be used in conjunction with the sighting units and the eyepiece whenever possible. When this combination of units is used and the person boresighting faces the target, the image will appear in its normal condition, that is, upright and with no reversal. This increases the ease with which the observer can direct the boresighting. There are other combinations of attachments possible which may be used in boresighting. However, the above combination is the only one which will give a normal image while the observer faces the target.

The recommended boresighting procedure for general use of the Mk 1 boresight kit is as follows:

1. Make certain that the GUNS ARE UNLOADED.
2. Remove the bolt from guns being boresighted and trip the accelerator to return the barrel to the battery position when boresighting from the breech of the cal. .30 and cal. .50 guns.
3. Select the breech adapter from the kit intended to be used with the particular caliber gun being boresighted.
4. Attach this breech adapter to the adapter connector on the breechsight. (See figs. 4–1 and 4–2.)
5. The wrench (fig. 4–1) fits the adapter slot in each adapter head, and is used to facilitate the attachment and removal of the adapter.
6. Orient the eyepiece connection (fig. 4–2) of the breechsight to point toward the person boresighting, then push the adapter firmly into the breech chamber.
7. Attach the necessary extension elements and/or the eyepiece element (fig. 4–1) to the breechsight.
8. Boresight the gun.
9. Reassemble the gun for firing.

In boresighting the guns from the muzzle, the normal procedure is to proceed as follows:

1. Clean the gun bore carefully. It is important to have the bore clean and free from fouling of all types.

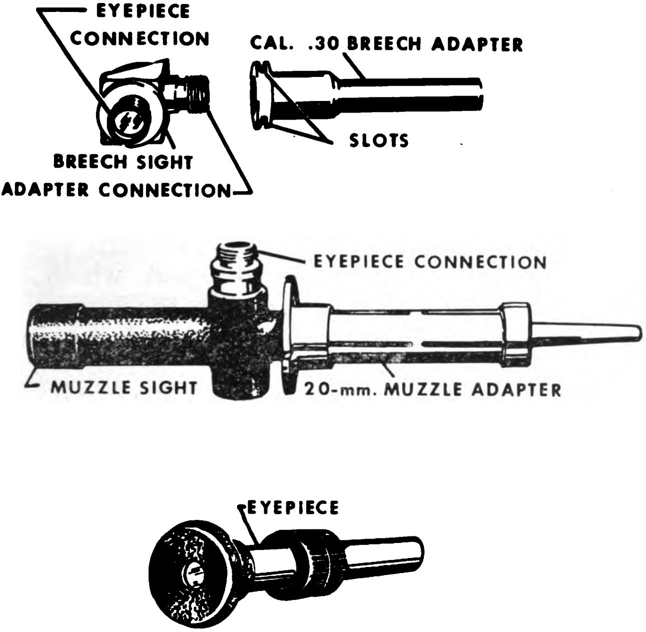


Figure 4–2.—Eyepiece and adapter combinations.

Dirt in the bore near the muzzle will cause a loose fit between the adapter and the sight unit. This will allow the sight axis to move with respect to the bore axis, thereby introducing an error in the cross hair and target alignment as shown in (B) of figure 4–3. In this connection, the boresight may be well off the target even though the gun bore axis is actually aligned with the target.

2. Select the muzzle adapter from the kit intended to be used with the particular caliber gun being boresighted. (See fig. 4–1.) Push it firmly into the previously cleaned muzzle of the gun.

3. Grasp the muzzle sight unit and, with the eyepiece connection (fig. 4–2) aimed in the most advantageous direction for attaching and using the eyepiece units, push the muzzle sight into the adapter as far as the tapered shaft of the muzzle sight post will allow it to go.

NOTE: After the muzzle sight has been inserted into the muzzle adapter, there will be no play between the adapter and the tapered shaft of the sight post. If there is any relative motion between the two, the barrel is either dirty or it is flared out at the muzzle due to service wear. Great care must be exercised by the observer to AVOID APPLYING ANY PRESSURE TO THE SIGHT UNIT WHILE IT IS IN USE. Otherwise a slight bend may be produced in the tapered sight post which would result in an error of several mils on the target. It is interesting to note that the breechsight is not subject to this trouble and error.

4. Attach the eyepiece and the extensions that may be required.

5. Boresight the gun.

6. After making the best possible adjustment, check the setting by rotating both the sight unit and the adapter 180 degrees. Use the trade mark on the adapter as a reference point. The muzzle sight must be removed before rotating the adapter to avoid scraping the adapter against the lands of the bore. Scraping of this nature would reduce the diameter and accuracy of the muzzle sight. During this rotation, if the cross hairs move off the target, it is due to the fact that the sight axis and the boresight axis were not accurately aligned. Such misalignment may have been due to an irregularity in the adapter or tapered post, or a slight bend in either. Should this misalignment be greater than 1 mil, it is highly recommended that the entire boresight kit be returned for overhaul. In the event that this is impossible due to certain operational commitments, the following procedure may be used in an emergency:

7. Rotate the sight 180 degrees and note how far the cross hairs have moved off the target. (See fig. 4–4.)

8. Readjust the gun so that the cross hairs are moved back toward the target—BUT ONLY HALFWAY. If the gun bore is in good shape, the gun will be in boresight even though the sight is not in perfect alignment. Since

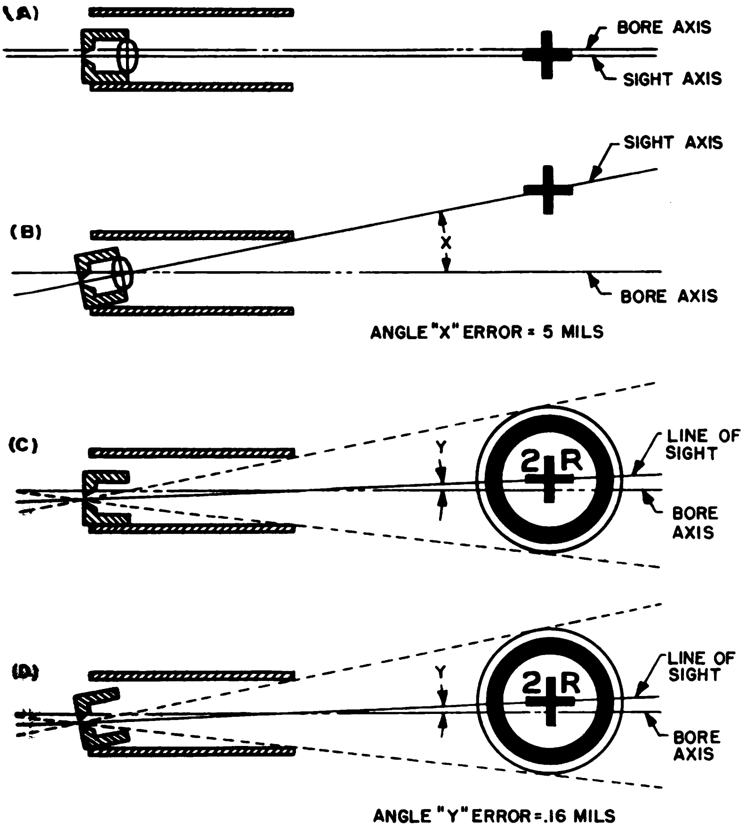


Figure 4—3.—(A) Breechsight with cross hairs (sight axis parallel with bore axis); (B) breechsight with cross hairs (sight axis tipped); (C) breechsight with no cross hairs (sight axis parallel with bore axis); and (D) breechsight with no cross hairs (sight axis tipped).

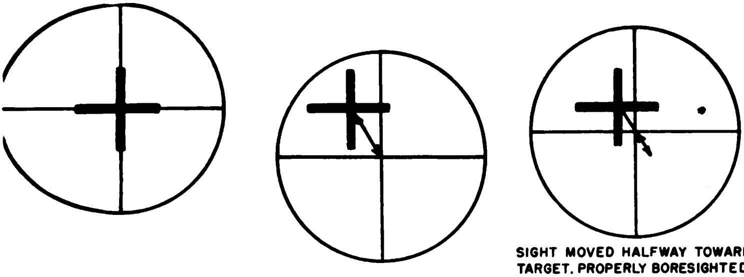
this procedure will not correct for irregular barrel bore wear or dirt in the muzzle, it is evident that the bore must be in good condition and clean before the adapter is inserted.

Figure 4–3 illustrates the theoretical comparison of boresight errors introduced by identical angular displacements of the breech adapters using a breechsight with cross hairs in the (A) and (B) portions, and the breechsight which has no cross hairs in the (C) and

(D) portions. Also in the (A) and (B) portions of the figure, there is illustrated the results which are obtained when cross hairs are used in the breechsight if the sight axis and the bore axis are NOT coincident. The sight axis may be considered to correspond to the axis of the breech adapter. Therefore, as long as this adapter fits snugly in the breech, the accuracy of this system is rather high; even in a loose fit the accuracy MAY be good as shown in the (A) portion of the figure. As an example, in figure 4–3 (A) and (B), the total clearance between the adapter and the breech is measured as 0.011 inch for purposes of illustration. This would indicate a moderate service wear condition.

Figure 4–3 (B) shows a more probable result in such a loose fit caused by a tipping of the adapter, and the consequent introduction of a small angle between the sight axis of the adapter and the bore axis of the gun. Computations in this instance will show that the maximum angular error is 5 mils with a clearance of 0.011 inch, or the angle *X* in figure 4–3 (B). Therefore, if the cross hairs are placed on the target, the gun is out of boresight by 5 mils. Figure 4–3 (C) and (D) shows that by using the breechsight having no cross hairs, it is not necessary to have the sight axis and the bore axis coincident. With the breechsight having no cross hairs, the line of sight passes from the center of the opening in the rear of the adapter through the center of the muzzle opening. It will be noted that the breech adapter in figure 4–3 (D) has been tipped through the same angle as was the breech adapter in figure 4–3 (B).

When boresighting a gun from the breech, the observer, by means of a breech adapter, breechsight, the proper extensions, and the eyepiece, positions his eye on the bore axis near the breech and uses the muzzle opening as the second point of reference. The heavily rimmed circle painted on the target screen used as the aiming point for boresighting should have a diameter, when erected at the proper boresight distance, slightly



SIGHT PROPERLY ALIGNED ON TARGET

SIGHT DISPLACED BY 180° ROTATION

SIGHT MOVED HALFWAY TOWARD TARGET. PROPERLY BORESIGHTED EVEN THOUGH SIGHT IS WORN OR BENT.

Figure 4—4.—Boresighting with misaligned sight components (emergency).

smaller than the outline formed on the target screen by the muzzle opening (looking from the breech) of the gun. (See fig. 4–3 (C) and (D).) When this painted circle on the target is centered so that an equal amount of outer background of the target screen may be seen on all sides between the circle and the inner diameter of the bore at the muzzle, the gun is boresighted. The fact that the muzzle opening may appear to be out of focus during this operation does not impair the accuracy of the boresighting results.

Tipping of the breech adapter which does not have the cross hairs incorporated has little effect on its accuracy. Figure 4–3 (A) and (B) illustrates the fact that as long as the bore and sight axes are parallel, both methods of breechsighting (i.e., cross hairs on a target cross, or muzzle opening on a target circle) are quite accurate. However, by looking at figure 4–3 (C) and (D) it may be seen that breechsights which contain cross hairs are a great deal more subject to errors in boresighting a gun having an unevenly worn bore, than those having no cross hairs. Actually, under this setup, boresighting errors up to 5 mils may be introduced, whereas, with the same barrel and using the proper target and the ADAPTER WITHOUT CROSS HAIRS, the error is reduced to 0.16 mil, or a negligible amount.

The conclusion to be drawn from the above discussion is that the most accurate method of boresighting is that accomplished from the breech of the gun. It is highly recommended that this procedure for boresighting be accomplished whenever possible in preference to boresighting from the muzzle.

The boresight target shown in figure 4–3 (C) and (D) is the type recommended by the Bureau of Ordnance. It consists of a ring (circle) whose annular width is 2 mils, and whose outer diameter is 10 mils. When this target is viewed from the breech of the gun, the muzzle openings of the cal. .30, the cal. .50, and the 20-mm subtend 12.5, 13.9, and 11.8 mils, respectively. In the center of the circle is a small cross, as well as a number and letter (2R), which denotes the particular gun of the aircraft for which this circle is to be used—in this case the number 2 gun on the right side of the aircraft. In boresight targets wherein these circles are close together or actually overlap as they sometimes do for convergence boresighting, distinguishing paint colors should be used along with the identifying letters and numbers for each gun or pair of guns.

Maintenance of the Mk 1 boresight kit elements consists mainly of keeping the exterior optical surfaces clean. The swivel joint of the angular extension should not be oiled, as some of the oil will eventually find its way down into the tube and onto the optics. No attempt should be made to repair or overhaul the optical parts of the kit. The kit should be sent to an authorized overhaul point when its components are in need of adjustment or repair.

Clearance Fixture Mk 1 Mod 0

This clearance fixture is used in conjunction with the Mk 1 boresight kit when boresighting turret guns. It is employed to measure the angular clearance of the cal. .50 aircraft turret guns over any portion or structural member of the aircraft. When the guns have been properly calibrated with this fixture, they will cease firing a preset number of degrees prior to the time the bore axes approach any structural member or surface of the aircraft, remain inoperative while the guns are swung past the member, and automatically start firing again a preset number of degrees past the member even though the gunner has held the firing and action switches depressed during the entire maneuver.

Before checking the various clearance points about the aircraft from the turret concerned, the guns have to be boresighted. The clearances have to be rechecked each time the structural interrupter is changed or adjusted, or when any other change occurs which affects the relationship of the guns, interrupter, or aircraft. An interrupter is necessary in the gun turret system to protect the various parts of the aircraft from gunfire from its own turrets. As the line of fire nears any structural member of the aircraft, interruption must take place between the limits specified in the applicable detailed turret specifications. As noted above, the guns are calibrated with the Mk 1 Mod 0 fixture so that the interrupter will actuate at the exact location desired.

NOTE: Care will have to be taken in the use of the Mk 1 Mod 0 clearance fixture as the graduated mil and degree scale thereon is calibrated in ARMY instead of NAVY mils. The conversion table below is given for convenience in converting the Army mil to the Navy mil for use with this fixture:

Army				*Navy*
6,400.000 mils	=	360°	=	6,263.600 mils
17.778 mils	=	1°	=	17.399 mils
3.375 minutes	=	1 mil	=	3.4883 minutes

The Mk 1 Mod 0 clearance fixture consists of a graduated head and a bronze adapter for fitting the fixture into the gun barrel. (See fig. 4–5.)

The arm serves as a holder for the muzzle eyepiece taken from the Mk 1 boresight kit. A trigger switch clamp, a set of test lamps, and a deflection marker complete the accessories needed for checking clearances. The test lights are handy in showing the action of the interrupter solenoids as they actuate, although the same test can be made by listening to the clicks of the solenoids to determine when they actuate. The deflection marker is used to check the deflection of the wings under flight loading conditions. Deflection diagrams for the aircraft concerned have to be consulted for the proper dimensions to be used in the construction of the deflection marker.

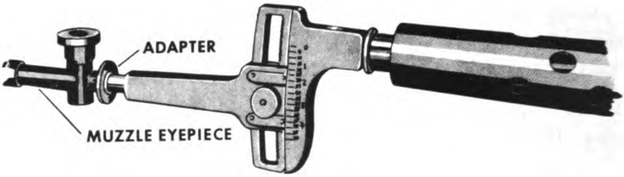


Figure 4–5.—Clearance Fixture Mk 1 Mod 0.

During the operation of the Mk 1 Mod 0 clearance fixture, it is first necessary to insure that all ammunition has been removed from the guns and that they are safe. An external source of power should be used unless the aircraft's APU is in operation. A trigger switch clamp is put in place over one of the firing grips to hold the switch in the firing position. The test lights are installed in the solenoid-interrupter leads, or someone may be stationed in the turret to listen to the clicks of the solenoids. (See fig. 4–6.) One of the action switches is held in the down position by a weight on a wire or other contrivance.

Although the power circuit of the turret may be energized, it is preferable to rotate the turret by hand because it can be held in the neutral position more readily in this manner than with the turret drive mechanism. If the turret is supplied with a selector switch, throw this switch to the BOTH GUNS position so that both circuits will be closed. Close the gun switch to the ON position. The actual clearance calibrations are commenced by selecting a convenient structural member such as a vertical fin upon which to make the initial check

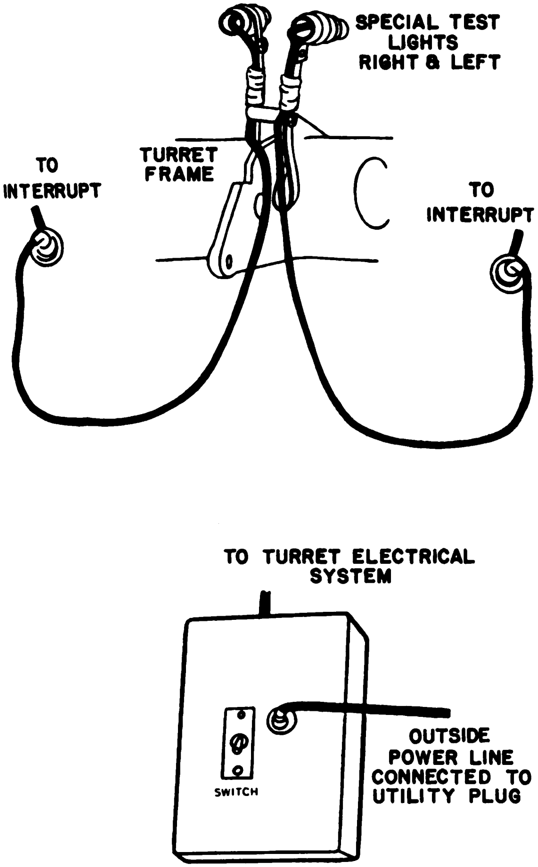

SPECIAL TEST LIGHTS RIGHT & LEFT
TO INTERRUPT
TURRET FRAME
TO INTERRUPT
TO TURRET ELECTRICAL SYSTEM
OUTSIDE POWER LINE CONNECTED TO UTILITY PLUG
SWITCH

Figure 4–6.—Test lights and switch box used with Mk 1 Mod 0 clearance fixture.

for clearances in elevation and azimuth. Insert the clearance fixture with its muzzle sight from the Mk 1 boresight kit into the muzzle of the gun to be checked. The clearance fixture must be rotated into a horizontal position for checking the azimuth, and into a vertical position to check the elevation clearance. It should be remembered that the protractor scale on the fixture must be positioned so that the scale READS TOWARDS THE ANGLE TO BE DETERMINED. In other words, the scale should read from zero degree DOWNWARD when reading OVER a position, and from zero degree UPWARD when sighting UNDER a position.

When checking clearances, always swing the turret from a firing position into a nonfiring position in order to simulate actual firing conditions. The reason for this is that if the turret were swung from a nonfiring postion into a firing position with an inherent 4-mil backlash in the interrupter, the firing area would appear to be 8 mils in the opposite direction. Swing the turret slowly into the position to be checked. When the test light cuts off thus showing that the guns are in the nonfiring position, look through the muzzle sight and turn the adjusting screw on the fixture until the cross hairs of the muzzle sight are aligned with the edge of the surface being checked. Lock the adjusting screw in this position by tightening the knurled locking nut, and read the angle on the protractor scale. This reading will be the angle included between the center line of the gun bore and the position being checked, and represents the CLEARANCE ANGLE. Repeat this process, but approach the same aircraft structure from the opposite side, and rotate the fixture so that the opposite angle may be read. The readings (in mils) taken are added together and divided by two.

Now the azimuth clearance is adjusted by setting the clearance fixture to the mean angle which has just been computed arithmetically, and locking the adjustment screw. Look through the muzzle sight and rotate the turret until the cross hairs fall on the edge of the structural surface. Without moving the turret farther, turn the azimuth interrupter gear adustment until the test light shows that the interrupter circuit has just opened or just closed. Use the above procedure on a horizontal stabilizer for an elevation check. If these tests have been accurately accomplished, other check points will prove to be correctly positioned and will check out in accordance with the specifications covering the aircraft type involved.

Boresight Screens

PREPARATION AND CONSTRUCTION OF THE BORESIGHTING SCREEN.—There are many basic factors to be considered prior to actual construction of a boresight screen to be used in conjunction with boresighting the armament of a particular aircraft. Determinations have to be made as to type of armament employed; type of sighting device used; range of the guns installed; range of the rockets and other armament installed; whether the guns are to be boresighted to converge or to be parallel; at what range or ranges they are to converge; the type and construction of the screen itself, as well as the materials from which it is to be made; whether the guns are to be boresighted parallel to the gunsight line, or whether these two are to converge at some point in the range of the guns; and many other details enter into the preparation of an accurate boresight screen.

There are several methods of boresighting the armament of an aircraft and harmonizing them with the sighting device. At one time a templet was employed which had inscribed boresight points for the guns and gunsight. It was attached to some part of the aircraft having a fixed relationship to the guns and the sight. The guns and sight were then boresighted to their respective points on the templet. Other and more recent methods have displaced the templet entirely. The boresight screen is responsible for this. The boresight screen, as such, has been supplemented by carefully plotting boresighting points on hangar and aircraft carrier bulkheads with which to boresight guns and other items of armament both ashore and afloat.

In the preparation of a typical boresight screen we go first to the *Handbook of Maintenance Instructions* for the particular type and model of aircraft involved. There may be found the tabulation of the VERTICAL and HORIZONTAL OFFSETS. These offsets denote in detail exactly how much offset distance there will be between the armament items and the gunsight in both horizontal and vertical directions. This information is needed in calculating the dimensions and detail plotting of the various boresight points on the target screen. Minor errors in making these calculations will be less damaging to the accuracy of the gunfire if the boresighting is performed for long ranges, and, conversely, at short ranges any such errors are greatly magnified; even to the extent of possibly causing complete misses in gunnery exercises or combat. Therefore, it is necessary to perform boresighting at the longest ranges compatible with existing local conditions as to range distances available.

The boresight target screen should be constructed of plywood, hardboard, or other suitably rigid material. It should have a weighted base or legs, and should be fitted with means of securing the entire unit against the wind. The dimensions should be such that all boresight points of the armament will fall well within the sides, as well as have sufficient space in which to plot the vertical and horizontal reference lines. These dimensions will have to be calculated with allowances for the distance the screen is to be used from the aircraft, and locations of the boresight points of the guns and other armament due to the type of boresighting being undertaken.

In detailing the construction of the boresight screen, a typical example will be used in which the guns of an aircraft are boresighted to converge at 1,000 yards, and the boresight screen constructed for use at 50 yards. (See figs. 4–7 and 4–8.)

The problem now is to locate those boresight points on the screen where the lines of fire and the line of sight should intersect the screen on their way to converge at 1,000 yards. We now know the vertical and horizontal offsets (taken from the *Handbook of Maintenance Instructions*), the range, and the distance the screen is to be in front of the aircraft. We need only to solve for the CORRESPONDING VERTICAL and HORIZONTAL OFFSETS to be plotted on the screen. The simplest method

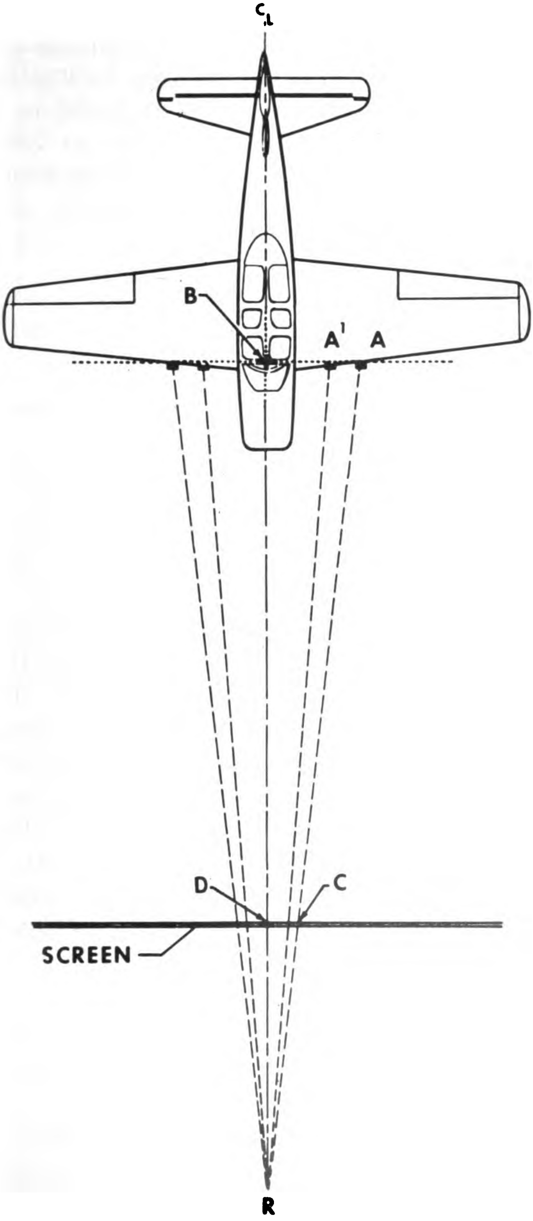


Figure 4—7.—Boresight screen construction—plan view.

of accomplishing this is to make use of similar triangles and solving for the unknowns by proportions. First of all, we solve for the corresponding horizontal offsets. The distance *AB* in figure 4–7 was found to be 158.6 inches, the distance *BD* has been given as 1,800 inches (50 yards), and the distance *BR* is 36,000 inches (1,000 yards). By placing these known distance values into a proportion we have:

$$\frac{CD}{AB} = \frac{DR}{BR} \text{ or } \frac{CD}{158.6} = \frac{34{,}200}{36{,}000}$$

$$CD = \frac{34{,}200}{36{,}000} \times 158.6$$

$$CD = 0.95 \times 158.6 = 150.6 \text{ inches}$$

Thus, we have found that the horizontal offset for the port outboard gun (at *A*) is 150.6 inches from the center line of the aircraft. In this particular boresighting problem, the line of sight and the lines of fire are to converge at 1,000 yards. The vertical offset of the gunsight will be greater than the vertical offset of the gun. Since this is true, the gun must be elevated if its lines of fire are to converge at 1,000 yards with the line of sight. It then follows that the corresponding vertical offset of the gun will be greater than the actual vertical offset. Thus, it is that we use the line of sight rather than the boresight datum line as the common base of the similar triangles. (See fig. 4–8.) The total computed vertical offset of the sight from the port outboard gun, the distance *AB*, is 57.5 inches. Again, substituting in the above formula, we have:

$$\frac{CD}{57.5} = \frac{34{,}200}{36{,}000} \text{ or}$$

$$CD = \frac{34{,}200}{36{,}000} \times 57.5$$

$$CD = 54.6 \text{ inches vertical offset}$$

The above solutions establish the linear distances from the vertical and horizontal reference lines drawn on the target screen at which the PORT OUTBOARD GUN

BORESIGHT POINT is to be plotted on the screen. Each remaining item of armament on the portside has to be calculated in the same manner as above. The gun at point *A′* is calculated next, and then the gun camera.

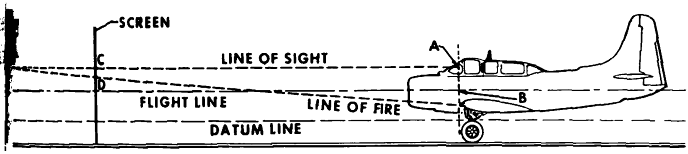


Figure 4–8.—Boresight screen construction—side view.

Since the lines *AB* in both figures 4–7 and 4–8 are in the plane of symmetry in both a horizontal and vertical aspect with regard to the guns and gunsight, all guns (and other armament) on the opposite (starboard) side may be plotted by employing the corresponding vertical and horizontal offsets established previously for the armament on the portside. In the event that a boresight screen has to be prepared for parallel boresighting instead of convergence firing, as illustrated in the above example, the offsets for the armament given in the *Handbook of Maintenance Instructions* for the aircraft concerned are all the information needed. These offsets may then be plotted directly on the boresight screen using the reference lines (vertical and horizontal) as the origin of all measurements. However, this procedure would not take into consideration the vertical offset between the gun bore line and the sight line. In other words, no ALLOWANCE FOR PARALLAX has been made.

In certain aircraft, all items of armament are boresighted parallel to each other and to the boresight datum line. In these instances it is not necessary to make an allowance for parallax, as the guns and the gunsight are close enough together and to one another to obviate the necessity of such an allowance. In some other instances the installation is such that the armament items are boresighted parallel, but the sight is offset from the guns to such an extent that an allowance for parallax has to be made. In other words, the guns have to be harmonized with the sight in the plane of the vertical offset so that the gunsight line and the boresight line converge at some point within the trajectory. In this case the CORRESPONDING HORIZONTAL OFFSETS will be the same as the ACTUAL HORIZONTAL OFFSETS. However, the CORRESPONDING VERTICAL OFFSETS will be different and will have to be calculated as shown in figure 4–8.

In laying out the boresight screen with the above data on offsets in hand, lay off a horizontal line running the full width of the screen near the bottom. A vertical line is then laid off in the center of the screen which is exactly perpendicular to the horizontal line. These are the REFERENCE LINES for the screen from which all boresighting points and other data are plotted. The intersection of these two lines normally form the BORESIGHT DATUM POINT on the screen.

The corresponding vertical and horizontal offsets previously calculated may now be laid off by careful measurements on the screen. When all such points have been laid off, a circle should be drawn around each point. These circles should appear to be slightly smaller in diameter than the circle seen from the gun barrel through the boresight telescope when viewing the screen which has been set up at the distance from the aircraft for which it has been designed. A circle of about 6 mils diameter may be seen through the bore of the gun. Therefore, the circles drawn on the screen should be slightly smaller than 6 mils. In the event that these circles are very closely grouped or actually overlap one another, it is a great aid to the personnel boresighting the guns and other armament to have the circles painted in contrasting colors even though they all have their designating numbers painted within the circles. A helpful practice is to paint the outboard gun boresight points one color, the middle gun boresight points another, and the inboard points still another. This procedure will expedite boresighting and may forestall serious boresighting errors occasioned by aligning a gun or guns with the wrong boresight point circle.

BORESIGHTING PROCEDURES

GENERAL CONSIDERATIONS.—Any aircraft operating activity will normally have periods in which there will be an opportunity to overhaul and boresight the armament of its aircraft. However, the leading ordnanceman working closely with the ordnance officer of the activity, will have to anticipate such periods carefully and schedule the necessary work accurately as past experience has shown that there will be little actual time in which the aircraft will be available for this important work. All possible arrangements should be made in advance of actual boresighting, so that the job may be carried out in the minimum length of time and with the least confusion. Different boresighting equipment and gear will be needed for different types of aircraft. This fact should be taken into consideration when accumulating the necessary equipment. Rockets and other types of missiles have become practically universal these days. Provisions have to be made for proper boresighting, or at least checking the boresight, of the launchers when necessary.

In certain instances, it may be necessary to use ramps when boresighting guns to set the aircraft at the proper boresighting position. In other instances, hydraulic jacks will have to be employed. At times it may be necessary to test fire the guns after boresighting. In performing this task, safety precautions must be carried out which involve alignment of guns with the butts, all pertinent precautions concerning loading and firing of the guns, and the ammunition to be used. Only ball or practice ammunition may be used for test firing into butts. This EXCLUDES ALL AMMUNITION OF PYROTECHNIC AND EXPLOSIVE CLASSIFICATION. There will be a variety of circumstances, other than the above, which demand additional or differing types of boresighting equipment. It will be the duty of those in charge of the ordnance phases of work in the unit to anticipate the needs of the unit, and see to it that all is in readiness for the relatively short periods of time in which boresighting and general ordnance maintenance work may be accomplished.

BORESIGHTING CREWS.—As a general rule, there will not be a great deal of time available to the ordnance division in an operating activity in which to boresight the armament of their aircraft. Many phases of daily operation necessarily take precedence over boresighting, and as a result, boresighting is sometimes relegated to a foul weather or spare time project. The leading ordanceman realizes this and should confer with his subordinates in laying out a workable and instantly available overall plan by which the aircraft may be kept in boresight. His plan should include a setup for boresighting single aircraft as they become available during or after routine checks, and should be flexible enough to handle an emergency situation in which ALL the aircraft may have to be boresighted at once, should it become necessary to switch boresight patterns or for other reasons. The basic unit in any planning of this type will be the BORESIGHTING CREW, or crews.

The leading ordnanceman should divide his men into crews, the composition and number in each crew being dependent upon the type of aircraft, the number of aircraft, the complexity of the boresighting job at hand, the number of ordnance and other personnel available to him, and other factors known to exist. He may divide the men into two groups, with a first class ordnanceman in charge of each group. Each of these two groups, or crews, may be further divided into crews with a third class petty officer in charge. No matter how divided, the leading ordnanceman should assure himself that each crew KNOWS what is to be done under each situation, and where to get the necessary equipment with which to do that particular job. Only with such a setup, or other equally careful planning, will the leading ordnanceman have confidence that his men will be able to meet the demands of this work.

One of the major items to be considered and planne for when boresighting current and future aircraft is the division of responsibilities between the Aviation Ordnanceman and the Aviation Fire Control Technician, and, at times, the Aviation Guided Missileman, and others. The duties of the AO and the AQ are pretty well defined in the *Manual of Qualifications for Advancement in Rating,* NavPers 18068 (Revised). However, there will be times when their duties may overlap one another, and if provisions are not made for such contingencies, confusion will result. Most overlapping that occurs may be resolved on the squadron level after proper considerations have been given by those concerned with planning and organization. Each subsequent change to the above manual delineates these responsibilities more closely so that there should be less and less overlapping.

In some situations the ordnance personnel may be supplemented in their work of cleaning and boresighting the guns by the aircrewmen. As each gun has to be cleaned prior to boresighting, this extra help will be welcome. However, dependence cannot always be placed in this source of extra help as it may not be available when most needed.

The gear used in boresighting consists of many items of heavy equipment in addition to the boresight kits. It may be necessary for the crews to use heavy jacks and hoists with slings. These items will most likely have to be borrowed from other divisions of the activity, or from a FASRon if such is near. Here again the leading ordnanceman will have to plan his boresighting so that maximum efficient use of this gear will be made by his men in order not to hold up others who may need these often used items. It will also be his responsibility to insure that each of his men is competently checked out in the gear to be used; be it the tractor, the boresight kit, jacks, hoists and slings, target screen, tools, or other items.

In the estimation of some, boresighting is just one of the "necessary evils" associated with operations. However, nothing will give the pilot in combat more self-assurance than to KNOW his armament has had the proper care and feeding, nor is there any other way for him to get the "kills" demanded than by having all of the armament in perfect working order and boresight. In spite of the trials and tribulations of getting all aircraft into perfect boresight and keeping them in this condition, there are few other items of greater importance.

A general plan for boresighting the aircraft of your activity might be as follows:

1. PLAN THE OPERATION.
2. Set into motion the boresighting crews previously organized.
3. Prepare the screens, if not already prepared.
4. Schedule the boresighting.
5. Check the equipment to be used for availability and condition. Do not overlook the condition of the safety features incorporated.
6. Move the gear to the boresighting area.
7. Move the aircraft to the boresighting area.
8. Carefully position the aircraft at the prescribed distance from the target screen, and elevate to boresighting position.
9. Boresight the gunsight(s).
10. Boresight the gun camera(s).
11. Boresight the guns.
12. Boresight all other armament (pods and launchers, etc.).
13. Have technicians boresight the fire control equipment (antennas).
14. Recheck all boresighting and alignment of the aircraft with the screen(s).
15. Safety wire, or otherwise secure, all adjustable features of the armament.

As first class and chief petty officers, you will be called on and required to teach and supervise the work of the rated men and strikers under you in all the phases of ordnance work of your unit. In addition, you will be called on to demonstrate certain phases of your work to the pilots of the activity. It is therefore expedient that your procedures and schedules be worked out to the best possible point in order that your time may be utilized most advantageously. As you well know, your work is quite apt to come in "spurts." Be prepared for this by planning ahead.

ANGLE OF ATTACK.—The angle of attack and the boresight datum line of the aircraft are intimately associated with one another. When the aircraft has been set up, or positioned, so that the datum line is horizontal, the aircraft may be said to have assumed its proper angle of attack for boresighting. This is true only because the manufacturer has previously calculated the angle of attack in its proper relation with the correct position of the aircraft under a definite set of conditions which are deemed to be the optimum for a particular flight condition of the aircraft. This set of conditions assumes the aircraft to be at combat speed (*V* max), critical altitude, a specified gross weight which takes into consideration that the aircraft is fully loaded less one-half the total fuel load, and other factors. When the aircraft is leveled and boresighted, its boresight datum line and the angle of attack will be in such relationship to each other that the fixed guns will hit the target at the specified range under the conditions mentioned above for the particular aircraft. If, on the other hand, the conditions of altitude, gross weight, angle of dive, accelerations of gravity, and airspeed are changed to values other than those set up as the optimum, corrections have to be made.

The manufacturer furnishes an angle of attack chart which affords the pilot a quick reference from which to pick off different values to be used under varying flight conditions and aircraft configurations. (See fig. 4–9.) If, as indicated in this figure, the gross weight of the

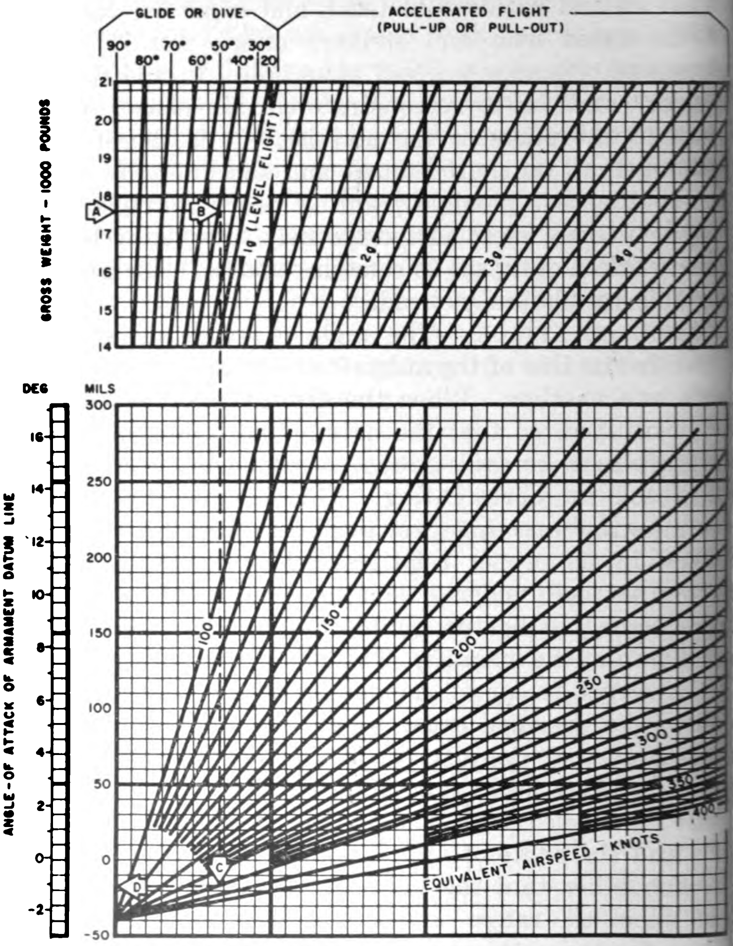


Figure 4–9.—Angle of attack relationship.

aircraft is 17,600 pounds (arrow A), the aircraft is to be flown in a 40-degree dive (arrow B), and at a stabilized diving speed of 300 knots (arrow C), the angle of attack of the armament datum line will be about –1 degree, or –17 mils (arrow D). A figure of –10.5 mils is also added in this particular case due to the fact that the dive brakes are open during the dive and produce a measurable effect on the flight attitude of the aircraft.

The two components, when added, give –27.5 mils. From these calculations the pilot will know that he has to RAISE his reticle in the gunsight 27.5 mils to compensate for the differential in the optimum conditions and the ones under which he is to fly this particular mission.

ALIGNING THE AIRCRAFT WITH BORESIGHT SCREEN.—In order to get the aircraft into proper position and attitude for boresighting its various items of armament, it is ordinarily necessary to align the armament boresight datum line with the horizontal. This is usually accomplished by sighting along the boresight datum line fixtures built into, or stowed within, the aircraft. These fixtures are constructed much as are the sights on small arms; that is, they are open sights, peepsights, or sights with cross hairs. There are numerous variations. Most are fixed, but some have adjustable features in order that the datum line may be changed to boresight various items of armament. They are normally fitted into the structure of the aircraft at locations best suited to the armament configuration concerned, and stowed therein at convenient locations. Regardless of where they are stowed or erected when in use, they are employed for one purpose—that of aligning the boresight datum line with the boresight target in order to boresight the armament. Reference lines which are normal (90 degrees) to one another are laid out on the target screen, and the sight lines of the boresight fixtures (also called boresight brackets) are aligned with the reference lines in both azimuth and elevation by shifting the aircraft or the screen. After these alignments have been made and the aircraft and the screen are secured in their proper positions, the aircraft is ready for boresighting.

Most of the boresight brackets are of the fixed type. That is, when once installed there is no further possible adjustment. However, there are some which do have an adjustable feature which is incorporated into the rear bracket, or fixture. In this type, the rear bracket usually contains cross hairs which may be adjusted up and down vertically so that the original boresight datum line (established when the cross hairs are adjusted to a certain scribed line on the bracket) may be altered to another scribed line to compensate the boresighting for varying armament configurations and/or gross weights.

There are certain restrictions placed on boresighting by the space available in which to erect targets. At shore stations the space may well be unlimited in which to erect the target, but aboard ship, such space is usually limited to roughly 50 feet. As a result, the targets used aboard are normally painted on parts of the superstructure on the flight and hangar decks. Wheel position points are usually painted at exactly the correct position in front of the bulkhead targets for all types of aircraft likely to be employed aboard. These points make it easier to position the aircraft for boresighting. On the beach, boresight screens made up for specified boresight ranges are normally used. They may be used for boresighting ranges at any specified range up to and including 300 yards or more. Some boresighting procedures call for a boresighting range of 1,000 yards or more, in which trees, standpipes, towers, and buildings may be used as boresight points. The farther the target is from the aircraft being boresighted, the more accurately its guns will be boresighted, other conditions being equal.

There are a great number of methods by which the aircraft may be set up for boresighting. The best of these methods for the aircraft concerned is outlined in detail by the manufacturer. One aircraft may be brought into a longitudinally level condition by elevating the tail, and jacking up the wings for leveling the lateral axis. Another may be leveled by easing the nosewheel down a specially prepared ramp and leveling the wings by adjusting pneumatic pressures in the oleos and tires. Still another may be leveled by the expedient of equalizing the pneumatic pressures in the oleos and tires for lateral leveling, and either inflating or deflating the nosewheel oleo for longitudinal leveling.

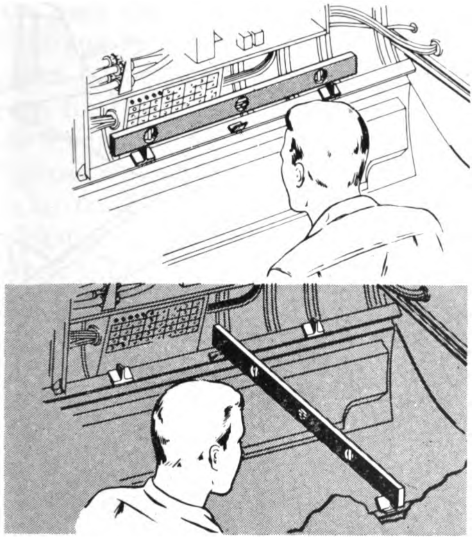


Figure 4–10.—Leveling lug provisions.

Leveling lugs are provided in each aircraft. A spirit level is placed on these lugs both in a fore-and-aft position for the longitudinal check, and in an athwartships position for lateral check during the leveling process. (See fig. 4–10.) Some of the larger aircraft make use of a plumb bob method for leveling. A plumb bob is suspended from a special hangar within the aircraft. A graduated chart, calibrated in degrees, is placed on a structural member over which the bob may closely swing. When the bob settles into the center of the chart graduations, the aircraft has been leveled. (See fig. 4–11.) There are other systems of arranging the plumb bob and scale, but they all perform the same duty, which is to indicate the exact position on the scale at which the aircraft has attained a level condition.

In spite of the fact that there are numerous methods of aligning the aircraft with the boresight screen, the fundamental purpose of any and all these methods is to position the aircraft so that its boresight datum line is parallel to the level ground or to a plane extended to

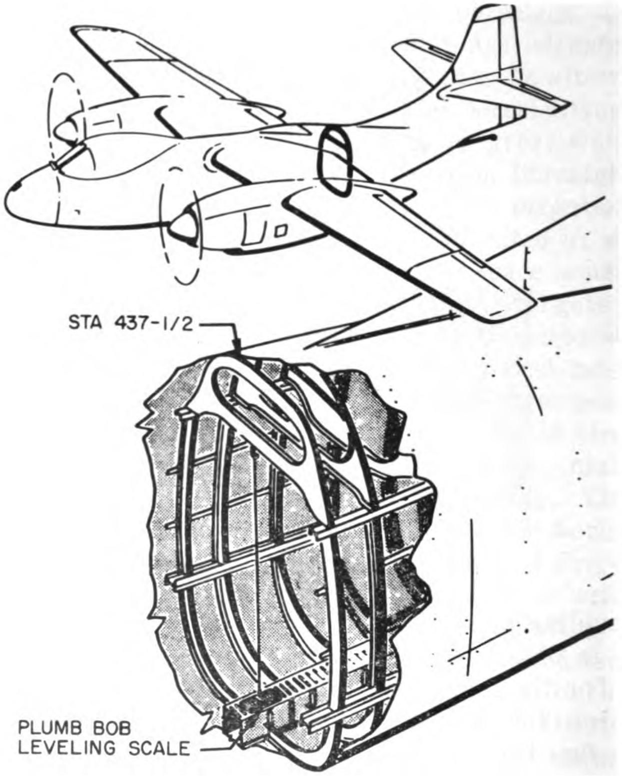


Figure 4—11.—Leveling device (plumb bob and graduated chart).

which the target screen is at right angles. The boresight screens, as well as the targets painted on bulkheads, have to be perpendicularly erect, parallel laterally to the lateral axis of the aircraft, and at the exact distance in front of the aircraft for which the screen or target is designed. This latter requirement is illustrated by the tolerance allowed by the *Handbook of Maintenance Instructions* in setting up the screen—plus or minus only 4 inches at a range of 1,000 feet in several instances.

BORESIGHTING THE GUNSIGHT.—After the aircraft has been leveled and the reference lines (horizontal and vertical) aligned with the boresighting fixtures on the aircraft, the next step is to align, or boresight, the gunsight (Mk 11 and Mods) with its proper boresight point on the screen. This point has been accurately plotted on the screen for the type of aircraft concerned. Entering into the computations of this boresight point will be the actual gross weight of the aircraft as loaded for the mission to be flown (less one-half the total fuel load), the flight tactics to be employed (level, diving, curvilinear, etc.), the airspeed, and the altitude.

Practically every mark and modification of gunsight has its own set of instructions for boresighting. This is due to the diversity of the mounting devices and to the mechanical makeup of the sights themselves. Since there are so many different types of sighting devices, it would be better to describe how only one of the currently used sights is boresighted.

An accurate job of boresighting cannot be performed if the sight itself is not accurately and SOLIDLY mounted. The boresighting procedure will have to be performed again if later it is found that the mounts are defective or loose. Check all mounts for defects, broken elements, and security **BEFORE** commencing to boresight.

Illuminate the fixed reticle of the gunsight to a comfortable brilliance, and operate the fixed reticle image selector knob to unmask the fixed reticle image. Observe the vertical alignment of the ladder markings of the fixed image as compared with the vertical reference line of the target screen. If they do not coincide, tilt the sight in the proper direction by turning the tilt boresight control until they do coincide. (See fig. 4–12.) The boresight cables are detented to lock every 90 degrees of rotation. Each cable is turned by inserting a screwdriver into one of the slots and pressing in until the detent is free. The cable then has to be turned in increments of 90 degrees because it may not be allowed to remain between the detents.

Next note the position of the center of the fixed reticle image with respect to the boresight point on the screen. If not coincident, the sight should be aligned by means

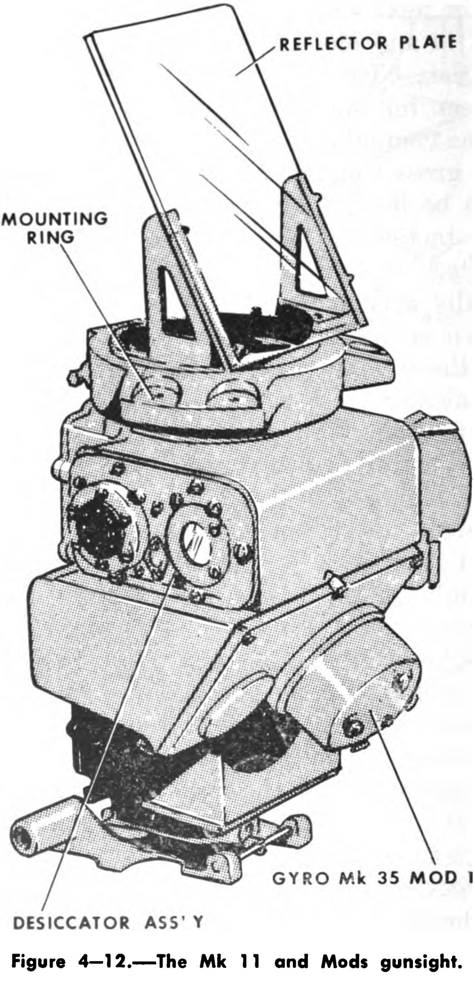


Figure 4—12.—The Mk 11 and Mods gunsight.

of the elevation boresight control and the azimuth adjustment screws. Turn the elevation boresight control to center the fixed reticle image vertically with the boresight point, then center the fixed reticle image laterally by loosening one azimuth adjustment screw while tightening the opposite screw. Recheck the orientation of the ladder steps of the reticle image (fixed) with the vertical reference line on the boresight target screen and make any minor adjustments found to be necessary. The gunsight is now in boresight.

BORESIGHTING THE GUN CAMERA.—The mounting assemblies and the methods of mounting the aircraft gun camera are many and varied. This 16mm motion picture camera has been mounted in practically every forward part of an aircraft in the many years that it has served faithfully to record for the pilots their hits, misses, and pictorial results of their practice and combat missions. Also, its ability to be placed at strategic locations to record the results of tests on the aircraft, its armament, and the physiological aspects of the human body undergoing accelerations of gravity and anoxia (oxygen deficiency) has made this camera a vital tool in all types of research.

There are a great many types of mounting systems for the gun camera when used for its original purpose of recording aircraft gunfire. In one installation, the gun camera is mounted in the wings of the aircraft at a point not too remote from the wing guns. In another installation, it is mounted on the ledge of the pilot's instrument panel in either a fore-and-aft position, or athwartships with an erector installed over the lens to reproduce the sequences in their normal aspect. Still another installation is within the turret. The installation possibilities are practically limitless.

As for the gun camera mounts, in one installation the mount will be an integral part of the aircraft, while in another the mount will be attached to the camera and the entire assembly bolted to the aircraft rigidly or attached by a hinge system to the aircraft for easy servicing in swinging outward. Regardless of the type of mount and the position of the camera within or on the aircraft, the mounts are adjustable in both elevation and azimuth. However, since the mounts and methods of attachment vary to such an extent, it is not practical to describe them in this chapter. Details of installing and adjusting gun cameras will be found in the *Handbook of Maintenance Instructions* for the aircraft concerned.

Boresighting of the aircraft gun camera is basically not too involved. It consists mainly of inserting a boresight tool, usually the AN–1 boresight, into the compartment normally occupied by the film magazine and making the necessary adjustments in elevation and azimuth through the boresight telescope so that the cross hairs of the boresight align themselves with the cross, or circle, on the boresight screen. In order to look through the camera, a straight-through telescope tube or a right-angle tube is selected from the boresight kit and fitted into the rear of the boresight body. The right-angle tube is used when there is insufficient room behind the gun camera for the operator to work conveniently. In this case he selects the elbow assembly and mounts the telescope tube at right angles to the axis of the boresight. (See fig. 4–13.) He is then enabled to rotate the telescope to a desired right-angle position for easy observation. Once the cross hairs of the gun camera boresight are aligned with the cross on the target screen and the azimuth and elevation adjustments properly secured, the camera is in boresight. As a final check, the image presented of the target screen boresight point through the boresight telescope should be rechecked after the camera has been secured. This check will indicate whether or not the camera has been forced out of boresight during the securing process.

NOTE: If, when the boresight is installed in the gun camera, the boresight's reticle does not align itself with the fiducial points of the gun camera, there is a misalignment of the boresight or the fiducial points of the camera have become dislocated. If the reticle (cross hairs) cannot be made to align with the fiducial points, the camera should be removed and replaced, as it would do no good to boresight the camera under this condition.

The AN–1 gun camera boresight is a precision optical instrument, and EXTREME CARE must be exercised in as-

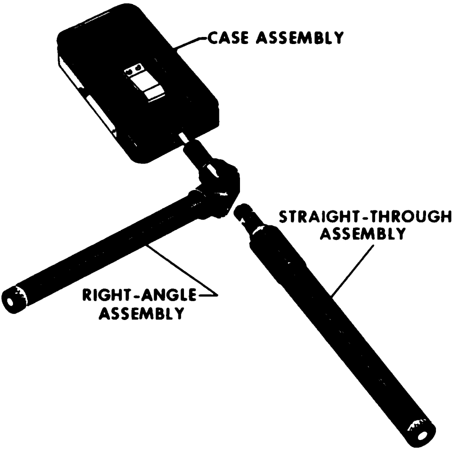


Figure 4—13.—AN—1 gun camera boresight.

sembling and handling this instrument. It should invariably be kept in its case when not in use. Avoid touching any of the optical surfaces with the fingers, and if the case should become dusty inside, clean with a vacuum cleaner. The optics of this instrument are made of optical plastics and demand great care in handling. There are only two cleaners for the optics which are authorized. One is pure castile soap in clean water, and the other is a one percent Aerosol (dioctyl sodium sulfosuccinate) solution in clean water. Cleaners or other liquids such as alcohol, acetone, etc. are prohibited.

BORESIGHTING THE GUNS.—A great deal of thought, planning, designing, money, and effort has gone into the the production and installation of the armament that equips our present day aircraft. This armament is installed for one major purpose—that of destroying any enemy with which we may be forced into open combat. If this armament is subject to frequent malfunctioning due to faulty design, faulty ammunition, incorrect maintenance and loading procedures, incorrect preservation and lubrication, and incorrect or slipshod boresighting, the pilot is flying around with a lot of useless weight aboard. While the ordnanceman cannot attend to all of these discrepancies, it is still his job to insure that the guns and other items of armament are in perfect alignment and in the best working order.

The basic step in boresighting is the alignment of the aircraft with the boresight target, be it either screen or a painted bulkhead target. This is accomplished in a variety of manners, but the major points to remember are that the screen and the aircraft are steady while boresighting and that they are at the specified distance apart. If the boresighting points are painted on a bulkhead, insure that the aircraft is squarely and solidly set in front of the bulkhead the prescribed distance. During the process of boresighting it is possible to displace either or both the aircraft and/or the screen by climbing over the aircraft or bumping the screen to such an extent that the otherwise carefully adjusted armament will not be correctly boresighted upon completion. It is therefore wise to check the alignment of the boresight brackets periodically during the process with the datum line boresight point on the screen. At the very least, the ordnanceman in charge of the boresighting crew should make such a check after the boresighting is completed, and BEFORE THE AIRCRAFT OR SCREEN ARE MOVED from their boresighting positions. At this time, if the boresight brackets are still in alignment and the boresighting has been accurately performed, it is safe to assume that the armament is in proper boresight.

There are a great many designs of mounts for aircraft guns. Essentially, these mounts serve but one major purpose, that of forming a rigid adjustable base within the aircraft upon which the guns may be installed. They have to be solidly constructed and anchored in order to absorb, without permanent distortion, the shock generated by the guns while firing. They must also have incorporated a means by which the guns are adjusted in both azimuth and elevation so that they may be properly boresighted. As a rule, these gun mounts are so designed that the guns can be removed from the mounts by releasing a locking device incorporated for rapid replacement of the guns or ease of maintenance work. Normally, the azimuth and elevation adjustments are incorporated into the rear trunnion of the mount when both trunnions are located under the receiver of the gun. When only the rear trunnion is under the gun receiver section, the forward mount will contain the azimuth and elevation adjustments. Provisions are made to positively lock these adjusting features once they have been set.

Due to the decreasing thickness of the wings in current high speed aircraft, and for other engineering reasons, guns are being placed in the nose rather than in the wings. New ammunition chuting and new feed mechanisms have been developed which require a great deal less space. As a result, the guns may be now placed much closer together than formerly possible and still leave ample room in the nose for other necessary gear. However, making adjustments to the mounts as in boresighting, and to other mechanical parts of these closely adjacent guns has brought about the need for specialized tools. As a result of this need, many new tools have been designed for specific adjustments and maintenance work on the guns. Many new designs have resulted from tools invented and constructed in the operating activities as a result of necessity; the design later receiving proper authorization from the cognizant bureau for production

While boresighting, it will sometimes be found necessary to check the clearances of the bore lines of the guns with their respective blast tubes. One simple method of checking for the proper clearance between the path of the projectile and the inner walls of the blast tube is to insert in the bore of the gun a brass rod of slightly smaller diameter than the caliber of the gun and of sufficient length to protrude beyond the end of the blast tube. By closely checking the clearances between the rod and the inside of the blast tube along its entire length, it may easily be determined whether or not the projectile will strike the blast tube at any point. The *Handbook of Maintenance Instructions* for the specific aircraft concerned will give the minimum clearances allowable.

For the purposes of illustrating a definite boresighting procedure, the AD attack type aircraft is selected. It more nearly fills the need for illustrating the overall boresighting problem because its guns are normally boresighted to converge; it has bomb racks and rocket launchers; it has ejection racks; it will be employed for some time to come in spite of the swing toward jet aircraft; it is adaptable to gun and rocket pods if the need arises; and because it has its guns in the wings, which, for illustrative purposes, makes graphic representation somewhat clearer.

It is natural that the procedure outlined below will vary to a great extent with the aircraft type involved, and in instances varies even between the different modifications of the same model aircraft. The boresighting equipment needed will be the Mk 1 boresight kit, the boresight brackets attached to or stowed in the aircraft, the target boresight screen or painted boresight points on a bulkhead, and the necessary jacking equipment. The forward boresight bracket is stowed in a spring steel clip beneath the front gun mount supports, and the rear bracket is bolted to the rear shear web and is folded along this web when not in use.

The aircraft is aligned with the boresight screen after proper positioning with the jacks, by means of the boresight brackets and their contained sights. Either of two boresight screens may be selected for the job. There is one for boresighting at 79 feet 4 inches, and another for use at 30 feet. As soon as the aircraft has been properly aligned with the boresight screen, the gunsight, guns, gun camera, and other armament may be boresighted. When the aircraft is in the recommended boresighting position, the gun bore line is parallel to the center line of the aircraft in azimuth, and is parallel to the armament datum line in elevation. In boresighting the AD aircraft, the inboard guns converge with the gunsight line at 600 yards in azimuth and 400 yards in elevation. The outboard guns converge with the gunsight line at 700 yards in azimuth and 300 yards in elevation.

The gun camera sight line is parallel to the aircraft center line in azimuth and parallel to the armament datum line in elevation. The inboard and outboard guns may also be boresighted to converge the fire pattern with the sight line at ranges varying from 250 to 1,000 yards in azimuth. The guns may be boresighted in elevation from a position that converges the fire pattern with the gunsight line at 400 feet, to a position in which the gunfire is parallel to the armament datum line. The gunsight and the gun camera have adjustment ranges in azimuth of ⅛ degree to the left and ⅛ degree to the right of planes parallel to the fuselage reference plane; and in elevation, of ⅛ degree above and ⅛ degree below planes parallel to the armament datum line, or flight attitudes ranging from 2.2 to 1.5 degrees nose down. It is usually expedient to use the boresight offset graphs to determine the amounts of boresight screen target ring offset in azimuth and elevation that will be necessary for boresighting the guns for various other ranges.

To align the aircraft with the target screen, first fold the wings. Then remove the front boresight bracket from the stowed position and place it in position on the forward mount supports and lock in place. Next, swing out the rear boresighting bracket and engage with the centering pins in the rear shear web. Repeat this procedure at the opposite wing joint. Jack up the tail of the aircraft at the proper jacking point until the fuselage reference line is nearly horizontal. As a safety precaution when jacking the aircraft, chock the wheels and attach a safety line, or preventer, to the tail section to prevent nose over due to wind gusts, etc. Move the target screen slightly in elevation and azimuth (but keeping the screen at the exact prescribed linear distance from the aircraft) until the sights of the left-hand boresight brackets align with the proper sighting point on the target screen. Check through the sights of the right-hand boresighting brackets and carefully shift screen, if necessary, until the mark on the screen bisects the boresight bracket sights. Secure the target screen and aircraft carefully in their respective positions.

Now that the aircraft and the target screen have been set up properly, the gunsight may be boresighted. Turn on the gunsight lamp switch and adjust the rheostat for optimum brilliance of the lamp. Place the elevation adjustment knob on ZERO elevation, and loosen the azimuth boresight clamp screws and adjust the mounting screws until the pipper is on the proper boresight point on the screen in azimuth. Tighten the azimuth boresight clamp screws, and safety wire the mounting screws. Correct for rotation of the reticle pattern by adjusting the azimuth boresight adjustment nuts up or down as necessary until the horizontal line of the reticle is parallel to the horizontal reference line on the boresight screen. If the pipper is off target in elevation, loosen elevation boresight clamp screw and adjust the mounting screw until the pipper is on target in elevation. Tighten the clamp screw and lock mounting screw to sight mounting bracket and safety wire.

NOTE: In this instance the elevation boresight adjustments should be made AFTER the azimuth boresight adjustments have been completed. This is because the azimuth adjustments move in an arc in the Mk 20 gunsight, and would upset the elevation adjustments were they to be made first.

The gun camera is boresighted next. Remove the gun camera access cover underneath the wing and insert the boresight fixture (Type AN–1 gun camera boresight) into the gun camera so that the eyepiece extends through the access cover opening. It is possible that nothing can be seen through the boresight due to the camera shutter being closed. In this case, actuate the camera test switch by flicking it to the TEST position until the shutter stops in the open position. This switch is mounted near the camera mount. Loosen the knurled locking knob on the camera mount and move the vertical adjusting knob until the horizontal line on the boresight screen and that of the boresight fixture are exactly coincident. Adjust the horizontal adjusting knob until the vertical line on the screen is coincident with that of the boresight fixture. Tighten the knurled locking knob, remove the boresight fixture, and close the gun camera access cover. The gun camera is now in boresight.

In BORESIGHTING THE GUNS, the inboard and outboard guns will be boresighted to different ranges and convergencies. Since this is the case in the AD aircraft, the guns will be boresighted in pairs; that is, the inboard guns boresighted alike and at the same time, and then the outboard guns together. To boresight the inboard guns, insert the necessary elements of the Mk 1 boresight kit into the breech of one of the inboard guns. Loosen the locking bolts at the bottom of the rear mount post, and rotate the cup until the horizontal line on the boresight screen and that of the boresight coincide. Loosen the locknut on the inboard end of the rear mount and rotate the bushing until the vertical line on the boresight screen and that of the boresight coincide. Finally, tighten the locking nut, and tighten and safety wire the locking bolt. The other inboard gun is now boresighted by the same procedure.

To boresight the outboard guns, the wings of the aircraft have to be spread. Before spreading the wings rotate each rear boresight bracket downward into its stowed position, and remove the forward boresight brackets and stow in the clips provided. After the wings are spread, loosen the camloc fasteners which attach the outboard gun access covers to the upper wing plating (atop the wing) and insert the boresight elements in the breech. Turn the azimuth control arm on the rear gun mount until the horizontal reference line on the boresight horizontal line coincide. Turn the elevation adjustment screw on the rear gun mount assembly until the vertical line on the boresight screen and the corresponding line in the boresight coincide. Securing of these adjustment features is necessary. The opposite outboard gun is boresighted in a like manner. At this point in the boresighting procedure, the alert boresighting crew leader will invariably recheck all the boresighting work done by his crew before moving either the aircraft or the target screen, and make sure that all tools have been removed and all adjustment points are secure.

As previously stated, practically every type of aircraft gun installation will have a different set of instructions for boresighting. The above description was given only as one example. Proper and accurate boresighting cannot be accomplished on ANY aircraft unless the detailed instructions for the specific aircraft and gun combination are consulted and carried out to the letter.

Boresighting the GUNSIGHT AND GUNS OF A TURRET is not too unlike boresighting the fixed guns. Essentially, it is necessary to rotate the turret to a position suitable to erection of the target screen. With the gun cradles at zero elevation, insert the elevation locking pins. Place a spirit level on each gun and level, if necessary, by loosening the locknut under the aft mount and rotating the externally threaded bushing that screws into the cast slide. Make each gun toe outward as far as possible by loosening the locknut under the aft mount enough to permit the eccentric bushing, whose flange is at the bottom of the cast slide, to be rotated across the serrations. Next, place the boresight into each breech. Erect the boresight screen so that the gun boresight points are level with the gun bore lines. Move the turret in azimuth so that each gun bore line is approximately the same distance outboard of its respective aiming point. Next, adjust the aft mount laterally so that the gun bore lines coincide with the gun aiming points, and secure the adjustments. The gunsight may now be boresighted and harmonized with the guns by adjustment until the FIXED CROSS of the gunsight coincides with the sight aiming point on the screen. The turret is now in boresight.

MISCELLANEOUS CONSIDERATIONS

CARE OF BORESIGHTING EQUIPMENT.—Boresight target screens, in addition to having to be laid out and constructed with meticulous care, have to be handled and stored with care. If the screen is broken or distorted, it loses a great deal of its accuracy, and is likely to give erroneous results during boresighting.

There are a number of highly specialized tools used exclusively for boresighting. They should never be allowed to go adrift and should have specified stowage spaces capable of being locked.

The boresight kits furnished to operating units are precision optical instruments, and should at all times be handled with this fact in mind. Any distortion of the settings of the components, misalignment of the optics, forcing of threaded joints and elbows, and damages to the optical surfaces will render the instrument useless. Erroneous results will follow any attempt to boresight guns with a boresight that has been damaged.

It should be a hard and fast rule that all jacking and hoisting equipment used in boresighting be thoroughly inspected prior to its use. It should be in perfect working condition as failure of any one of the components might well result in extensive damage to the aircraft and injury to boresighting personnel.

PREPARING AND ERECTING BORESIGHT SCREENS.—The details of constructing a boresight target screen have been previously given. However, accuracy in laying out the boresight points from the reference lines cannot be overstressed if the guns and other armament are to receive the proper boresighting. Most of these screens are constructed to be used at some point within the range of the guns—usually rather close to the guns. If an error were made in laying out any of the boresight points for a screen which is to be placed somewhere between 30 and 80 feet in front of the guns, the corresponding error of the gun boresighted to this incorrectly plotted point at the maximum effective range of the gun (3,200 feet) would be tremendously magnified. The target would not be missed by inches; it would be missed by feet despite the fact that the pilot had tracked smoothly and fired only when squarely "on."

These same points obtain when plotting and painting a target on a bulkhead, as this type of target is also used at close range—around 50 feet. Definite markings have to be made on the deck for wheel positioning in front of the target. Insure that each set is clearly marked so that the type of aircraft being boresighted will be centered over the correct set. In addition, all other positioning references for the aircraft, such as plumb bobs, etc., have to be centered over their proper marks prior to commencing boresighting. Various combinations of equipment, such as jacks, hoists, slings, chocks, sandbags, etc., will be needed for the different types of boresighting procedures.

POINTS TO CHECK WHILE BORESIGHTING.—During the process of boresighting, there are a number of places in which troubles may be experienced. In order to obviate as many of these trouble points as possible, it will be helpful to check on the following items prior to and during boresighting:

1. A live round may still be in the chamber.
2. The guns may not have been cleaned, thus causing the boresight to fit improperly.
3. There may be broken or distorted parts in the gun.
4. The boresight target screen may be the wrong type for the aircraft being boresighted.
5. The aircraft may not be properly positioned for boresighting, and this fact may not be noticed until too late, causing all previous work to be repeated.
6. Guns may inadvertently be boresighted to the wrong boresight points on the screen. In some installations this fact may show up when trying to replace the nose cowling, and a binding occurs as the blast tube strikes the gun muzzle instead of slipping over it as it should. In other installations this fact may not even show up at all.
7. The gyro reticle may have been used to align the gunsight with the target instead of the fixed reticle thus introducing an error.
8. The boresight brackets and their sights attached to the aircraft may be bent or broken.

9. The crew might attempt to boresight a gun badly roded at the breech or muzzle. This would cause an mproper fit of the boresight element.

10. Boresighting may have been accomplished in pite of the fact that the gun mounts were defective, roken, or misaligned. New mounts will have to be intalled and the boresighting repeated. Always check the nounts prior to boresighting.

11. The gunsight may be out of collimation, and the rewmember boresighting this unit probably would not ave looked through the sight from exactly the same eye osition each time during boresighting. The sight will ave to be corrected or replaced and the boresighting epeated.

12. Someone may have forgotten to safety wire some f the adjustments during the boresighting process. A areful check on this point is a necessity.

SAFETY PRECAUTIONS FOR BORESIGHTING

There is danger associated with all phases of ordnance ork. Boresighting is by no means an exception. **BOREIGHTING MAY BE CONDUCTED SAFELY ONLY WHEN THOSE ARTICIPATING IN THIS WORK ARE ABLE TO RECOGNIZE AND NDERSTAND THE CAUSES AND EFFECTS OF ALL THE REAL ND INCIPIENT DANGERS ASSOCIATED WITH THIS WORK, ND ARE THEREBY ABLE TO AVOID AND PREVENT THEIR OCURRENCE.** Listed below are some of the precautions hich should invariably be taken in connection with boreighting. Some of these may seem inconsequential, but re generally found to be more far-reaching than at first upposed:

1. One of the primary precautions is to insure that all ersonnel concerned have a complete understanding of he operation of boresighting. This does not necessarily nean that the man whose only job is driving the tractor hould know how to boresight all the guns on a P2V type ircraft. However, it does mean that those whose job it

is to boresight the guns should know all of the procedures and safety precautions therewith associated.

2. Either remove all external loads such as bombs, rockets, underwing tanks, and internal stores in bomb bays, or take the necessary precautions to make these loads safe by the use of safety pins, deenergizing the releasing circuits entirely, or by disconnecting the manual releases.

3. Use only tractor drivers who are thoroughly checked out, and the proper towing gear in each instance.

4. Make use of elevated platforms or other types of check stands so that boresighting personnel may avoid clambering over the aircraft during boresighting.

5. Check the output voltage of the auxiliary power unit (APU) if such is used. This voltage should be approximately 27.5 volts.

6. Stay clear of the line of fire at all times. Even when boresighting from the muzzle with the bolt group removed, this practice should be enforced.

7. The boresighting crewmember in charge should PERSONALLY CHECK TO INSURE THAT THE FEED MECHANISMS ARE DISCONNECTED, THE T-SLOT AND CHAMBER ARE EMPTY EACH TIME BEFORE ALLOWING THE BOLT GROUP TO GO FORWARD INTO BATTERY AND ELECTRICALLY FIRED, AND THAT NO DELINKED ROUNDS ARE LEFT IN THE COMPARTMENT.

8. When removing the bolt driving springs, be sure th bolt group is in the battery position, as these springs are still under moderate compression even in this positio

9. Never mechanically block or electrically "jump" th disabling switch. This device is placed in the gunfirin circuit for making the guns safe whenever the landin gear is lowered, either in the air or on the ground.

10. The bolt groups should be removed from all gu being boresighted either from the breech or muzzle.

11. Insure that the jacking and hoisting equipment t be used in boresighting is of sufficient capacity (plus safety margin) for the job at hand.

12. Always use the safety locks on the hoists and jacks nce the aircraft is in the proper boresighting position.

13. While jacking an aircraft, check the jack feet to isure that the load weight is being evenly distributed nd that the jacks do not become off balance.

14. The jack pads should be checked during the jack- ig process to insure that no slippage or shifting of eight occurs.

15. When an aircraft with tailwheel type landing gear being boresighted, its center of gravity tends to ro- ite around the main landing gear as the tail is elevated. s the longitudinal axis of the aircraft approaches the orizontal, a nosing over moment may be experienced. andbags placed across the fuselage and on the horizon- il stabilizer roots, preventer lines around the fuselage t the tail and anchored to a pad eye in the apron, or her suitable means must be employed to prevent pos- ble upset.

16. When using a tail jack and two wing jacks, ele- ite the three at the same rate so as not to unbalance ie aircraft.

17. Always handle the boresight kit carefully as it is recision made optical equipment, and therefore very elicate.

18. If test firing is to be conducted to check boresight- ig, have sound powered communication equipment in- alled in the butts and at the aircraft site to expedite erations and serve as a safety measure.

19. When aircraft is being boresighted or its guns eing test fired while on a ramp, serviceable chocks have be carefully fitted in place about the wheels and the rcraft properly secured.

20. Before boresighting or test firing the guns, check ie gun mounts for worn components, security, and roper installation. Also CHECK TO INSURE THAT THE JNS ARE ACTUALLY LOCKED INTO THE MOUNTS.

21. In large aircraft in which two or more turrets ay be boresighted during the process, care should be iken not to overload the APU's.

22. In organizing the crews to boresight aircraft armament, limit the personnel only to those essential in the actual boresighting work and those who must observe for training purposes.

23. After boresighting has been completed, safety wire all adjustable elements or otherwise secure them to specifications, and check the aircraft compartments for tools and equipment that may have gone adrift during the work.

24. Always check to insure that ALL the boresight elements are back in the boresight kit after boresighting is completed. Instances have occurred in which the boresighting adapter and muzzle elements have been left in the gun muzzles with fatal results to personnel.

It is hard to find time and incentive to lay proper emphasis on safety precautions due to the commitments of daily routine operation and other distractions, YET ACCIDENTS OCCUR DAILY WHILE CARRYING OUT THESE SAME ROUTINE OPERATIONS. The obvious remedy to correct for such a condition to the greatest possible extent is to FIND time and impress on each person involved the seriousness of knowing, understanding, and complying with all pertinent safety precautions. The more a man knows about the why's and wherefore's of safety precautions, the less he is likely to forget the precaution itself. Never simply tell him to lower the jacked-up aircraft at the same rate at each jacking point, for instance. Give him the whole story about lowering too rapidly on any one of the jacks. Tell him of the relative ease with which an aircraft can and has slipped off the jacks when raised or lowered unevenly. Make sure he KNOWS he may do strike damage to the aircraft and kill himself to boot. This is an elementary example, but when it comes to safety, a lot of us never get out of the elementary grades!

QUIZ

1. The swivel joint of the Mk 1 boresight kit angular extension is
    - a. cleaned with kerosene
    - b. cleaned with OS 1361
    - c. lubricated with oil similar to "3-in-1"
    - d. none of the above
2. The repair and overhaul of the Mk 1 boresight kit should be done by a/an
    - a. ordnanceman
    - b. factory
    - c. Navy supply point
    - d. authorized overhaul point
3. The clearance fixture is used on aircraft
    - a. with guns in wings
    - b. with guns in nose
    - c. when boresighting turrets
    - d. when tube extends from gun through nose of the aircraft
4. The apparent angular field of the Mk 1 boresight kit telescopes (when assembled with other elements of the kit) is
    - a. 2 degrees
    - b. 2 degrees, 15 minutes
    - c. 3 degrees
    - d. 4 degrees
5. The combination of attachments of the Mk 1 boresight kit that will give a normal image while the observer faces the target is a
    - a. breech adapter for .30 cal.
    - b. 20-mm breech adapter
    - c. straight and angular extension used with sighting units and eyepiece
    - d. breech adapter for .50 cal.
6. The first step in boresighting procedure when using the Mk 1 boresight kit is to
    - a. remove the bolt from gun
    - b. make certain the head space is correct
    - c. take the backplate off the gun
    - d. make certain the guns are unloaded

7. The technique of making the gunsight and armament work together is known as
   a. mean point of impact
   b. arriving at boresight datum line
   c. boresighting
   d. arriving at vertical gun offset

8. The bore axis is known as a straight line through the bore of the gun extending
   a. into infinity
   b. 1,000 yards
   c. 100 yards
   d. 50 feet

9. The templet used for boresighting was replaced by
   a. a muzzle sight
   b. a screen
   c. boresighting on nearest water tower
   d. placing guns in wings of the aircraft

10. When guns are boresighted parallel to each other, the lethal density will
    a. vary with the airspeed
    b. vary with the target range
    c. vary with the aircraft attitude
    d. not vary throughout entire range of guns

11. The effects of dispersion at the target will be notably less when guns are
    a. boresighted in parallel
    b. boresighted to converge
    c. boresighted in a combination parallel and converging pattern
    d. mounted in wings

12. Dispersion of each individual gun is due to the
    a. rigidity of long barrel
    b. rigidity of gun mounts
    c. muzzle whip or jump
    d. all of the above

13. The difference in mils between each degree of arc as calibrated by the Army and the Navy is
    a. 3.4883
    b. 3.3750
    c. 0.379
    d. 0.793

14. The designation of the clearance fixture is
    - a. Mk 1 Mod 1
    - b. Mk 1 Mod 0
    - c. Mk 3
    - d. M–1

15. When checking clearances, always swing the turret
    - a. from firing position to nonfiring position
    - b. from nonfiring position to firing position
    - c. to the vertical up position
    - d. forward and horizontal to the aircraft

16. The most accurate method of boresighting is accomplished
    - a. from the breech of gun
    - b. from the muzzle of gun
    - c. by a combination of muzzle and breech boresighting
    - d. by the ordnanceman sighting down barrel of the gun

17. The optics of the AN–1 gun camera should be cleaned with
    - a. pure castile soap and clean water
    - b. alcohol
    - c. acetone
    - d. 50% alcohol and 50% acetone

18. Minor errors made while boresighting at short range
    - a. will be greatly magnified at long range
    - b. will be minor at long range
    - c. will give the same results regardless of range
    - d. are expected, but the effects are negligible

19. When determining the angle of attack, the manufacturer calculates for
    - a. combat speed
    - b. critical altitude
    - c. gross weight
    - d. all of the above

20. The diameter of the circle in mils seen through the gun while boresighting from the breech should be about
    - a. 2
    - b. 3
    - c. 5
    - d. 6

21. The angle in degrees formed by the reference lines of the boresight screen is
    - a. 45
    - b. 60
    - c. 90
    - d. 180

22. When test firing guns into butts after boresighting, the ammunition to use is
    a. all types for correct results
    b. incendiary and tracer belted one and one
    c. ball or practice ammunition only
    d. HEI ammunition only

23. An angle of attack chart giving the pilot a quick reference under varying flight conditions and aircraft configurations is furnished by/found in the
    a. *Handbook of Maintenance Instructions*
    b. *Flight Handbook*
    c. manufacturer
    d. *Illustrated Parts Catalog*

24. Leveling the aircraft in preparation for boresighting will vary according to the aircraft. It may be accomplished by
    a. estimating the approximate level
    b. using the gunsight
    c. the plumb bob only
    d. the plumb bob and chart or spirit level

25. Information on boresighting a specific aircraft may be found in the
    a. *Pilots' Handbook*
    b. *Index of Ordnance Publications* (OP 0)
    c. *Handbook of Maintenance Instructions*
    d. *Illustrated Parts Catalog*

CHAPTER 5

LINKING AND DELINKING EQUIPMENT

The Army-type Link Loading Machine M16 (fig. 5–1) is a portable unit with carrying handles located on the sides and rear of the mounting frame. It is normally powered by a one-quarter horsepower motor, but may be operated manually in the event of power failure. Operating speeds of the M16 are adjusted through a variable diameter pulley on the motor shaft.

The M16 is designed to mechanically assemble 20-mm cartridges into metal clips to form a continuous belt of ammunition for use in 20-mm guns. Attachments are provided to convert this machine to function as a delinker for the disassembly of an ammunition belt into its components. An adjustment is provided to allow use of various types of links in forming the belt.

Attachments and accessories for the link loading machine include a manual drive handcrank, the parts used only for linking operations, and those used only for delinking operations. The handcrank replaces the handwheel on the handwheel drive shaft for manual operation of the machine. The attachments for the linking operation include the ammunition tray, link chute, linking loading wheel guide, ammunition feed assembly, and two pushers. Special attachments used only for delinking are the delinking loading wheel guide, loading wheel shield, and two ejectors.

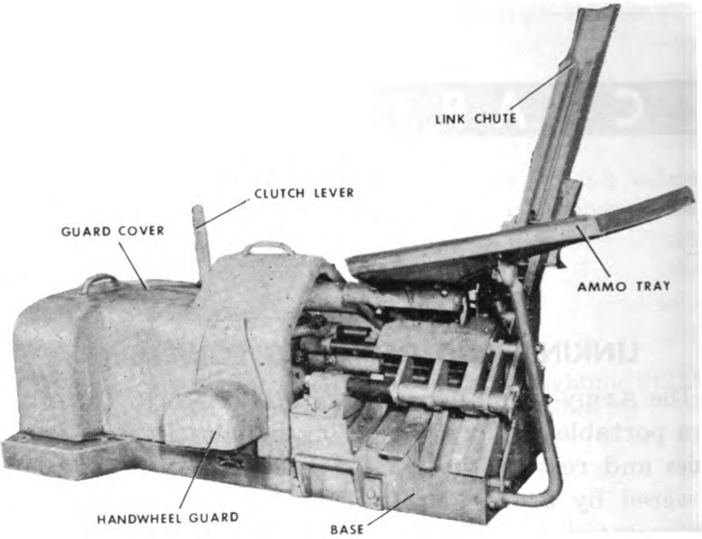


Figure 5–1.—20-mm Link Loading Machine M16.

When assembled for operation, the M16 linking machine has the following characteristics:

Length	54⅝ inches
Width	47½ inches
Height	33⅝ inches
Weight	300 pounds
Operating speeds:	
Powered linking	85–150 rounds per minute
Powered delinking	85–250 rounds per minute
Manual operation (average)	60 rounds per minute

The major components of the M16 link loading machine are either mounted on or attached to a single main base. The drive assembly is mounted on the rear portion of the frame and includes an electric motor, a drive shaft assembly, and a clutch shaft assembly. All shaft bearings are provided with lubrication fittings. The motor has an adjustment for operating speeds within the limits shown in the above paragraph. The drive shaft is connected to the drive pulley through an overload release mechanism which disengages the clutch in the event the machine is jammed.

Connected through a pair of bevel gears at the front end of the drive shaft, is a handwheel shaft to which a handcrank may be attached for manual operation. The clutch shaft, connected to the drive shaft through a friction disk-type clutch, has a Geneva crank mounted on its after end. This crank engages a Geneva wheel, mounted on the rear of the loading wheel shaft, and imparts intermittent rotary motion to the loading wheel shaft. Connected to the front end of the clutch shaft, through a pair of bevel gears, is the pusher crankshaft. Pushers, operated by this crank, insert the cartridges into the links. Index marks on the bevel gears provide a reference with the Geneva crank, so that the continual reciprocating action of the pushers is synchronized with the motion of the loading wheel unit.

The loading wheel unit, which is keyed to the forward end of the loading wheel shaft, guides the cartridges and links through the assembly points and carries the linked belt out of the machine. The intermittent rotary action of the loading wheel unit is so coordinated with the reciprocating action of the pusher mechanism that a cartridge and link are presented at the point of assembly during the recovery stroke of the pushers. A lever at the front end of the machine adjusts the link sprockets on the loading wheel unit to accept the available types of links.

The feed mechanism is assembled in a large steel casting. When assembled to the linker, the feed wheel shaft is connected through gearing to the loading wheel shaft which imparts intermittent rotary motion to the feed unit. This unit receives the cartridges from the ammunition tray and conveys them to the loading wheel unit. A gravity feed link chute, assembled to the feed unit, delivers the links to the link retaining sprockets on the loading wheel shaft. A vibrator assembly, which is designed to interlock the links and aid the gravity feed, is incorporated in the link chute. This assembly is actuated by a vibrator lever and rod. The lever and rod are pivoted on the feed unit support. The vibrator lever is actuated by a cam on the pusher crank.

M16 LINK LOADING MACHINE

Description

MOUNTING ARRANGEMENT.—All elements of the M16 link loading machine are mounted on a single cast aluminum base. This base supports the clutch bracket, Geneva bracket, loading wheel front support, loading wheel guide bracket, and components of other assemblies as shown in figures 5–2 and 5–3.

BASE ASSEMBLY.—The base assembly consists primarily of an aluminum casting to which four carrying handles are bolted, two on the rear and one on either side. Two hardened steel strips, bolted to the forward left side of the base, serve to guide the belted ammuni-

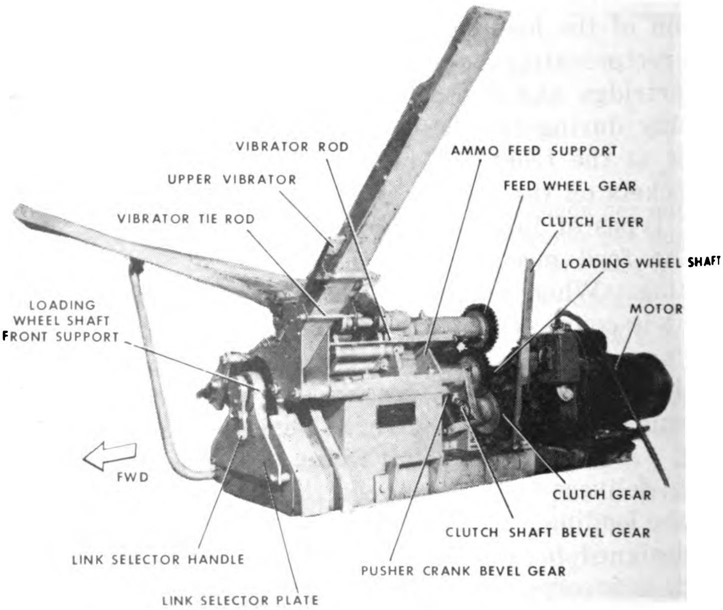


Figure 5–2.—M16 link loading machine showing arrangement for linking operation.

tion into the machine for delinking. A similar pair of guide strips on the forward right side guides the ammunition belt out of the machine after linking. A third set of guide strips is bolted to the right side and serves to guide the ammunition out of the machine after delinking.

The base assembly provides mounting or support for the above guide strips and, in addition, mounts the feed assembly, clutch lever, overload release, electric motor bracket, loading wheel shield, and guard cover.

CLUTCH BRACKET.—The clutch bracket (fig. 5–3) is bolted to the base casting and is positioned by two dowel pins. This bracket is a triangular-shaped aluminum casting arranged to support three horizontal shafts and and another shaft which lies at an angle of 36 degrees from the vertical. These four shaft openings are provided with needle bearing inserts. The clutch bracket supports the center of the loading wheel shaft in its upper bearing, the forward end of the clutch shaft in the lower left bearing, and the forward end of the drive shaft in the lower right bearing. The pusher crankshaft (the fourth shaft) is supported in needle bearings at each end at an angle of 36 degrees to the right of vertical. Of the above bearings, only the clutch shaft bearing does not have a lubrication fittting. This bearing is lubricated through a fitting in a bevel gear on the end of the shaft.

GENEVA BRACKET.—-The Geneva bracket shown in figure 5–3 is a triangular-shaped aluminum casting which provides support for three shafts. Bolts and dial pins position this bracket at the rear of the mounting base which supports the after ends of the drive shaft, clutch shaft, and the loading wheel shaft. These three shafts are supported by needle bearings and are lubricated through fittings in the bracket.

LOADING WHEEL FRONT SUPPORT.—The loading wheel front support shown in figure 5–2 provides a ball bearing support for the forward end of the loading wheel shaft, and has an axial adjustment for the link retaining

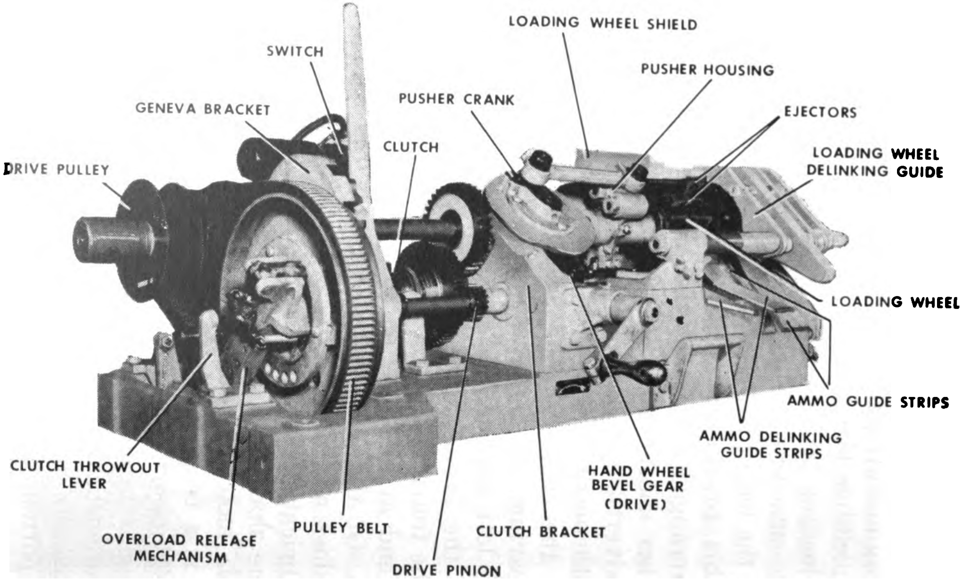


Figure 5–3.—M16 link loading machine showing arrangement for delinking operation.

sprockets. The cast aluminum support contains a ball bearing mounted in an adjustable screw and a link selector plate. It is bolted to the front part of the base casting, extends upward, and has a large threaded hole at the top. A threaded cylindrical screw fits into this hole and houses the loading wheel shaft ball bearing. A link selector handle is bolted to this screw to facilitate rotation of this screw for adjustment to various types of links.

The roughly triangular-shaped link selector plate is fastened to the front face of the base by two screws. Spacers behind the plate separate it from the support. The upper part of this plate has a stop pin to limit rotation of the link selector handle. Detents in the plate act as stops for the link selector handle for the various types of links being used.

LOADING WHEEL GUIDE BRACKET.—This component is an L-shaped bracket bolted and doweled to the top of the right forward part of the base casting as shown in figure 5–3. The upper portion of this bracket is drilled to receive a loading wheel guide mounting stud horizontally. The loading wheel guard is secured to the outer surface by two wing screws. The stud is secured in the bracket by a nut and washer at the rear end. The other end of the stud supports the loading wheel guide and has a machined groove which is engaged by the loading wheel guide latch.

DRIVE ASSEMBLY.—The components forming the drive assembly are the electric motor, switch, motor pulley belt, drive pulley, drive shaft, drive pinion, clutch gear, clutch, clutch shaft, pusher crank drive gear, Geneva crank, handwheel drive, and the overload release mechanism. (See figs. 5–2 and 5–3.)

ELECTRIC MOTOR.—A single phase, capacitor-type, explosion-proof motor, which operates on 115/230-volt, 60-cycle alternating current, is the prime mover for the M16 link loading machine. It is mounted on an adjustable hinged table near the rear of the base casting on the left side. This motor runs at 1,140 r.p.m. and draws up to 4.6 amperes on the 115-volt current under full load. When wired for 220 volts, the motor draws 2.3 amperes.

MOTOR SWITCH.—This switch is a typical ON-OFF toggle switch arranged to start and stop the drive motor. It is mounted on a bracket attached to the motor housing. The power for the motor enters through the toggle switch from a two-conductor cable that terminates in a standard two-pronged plug, for use with 115 volts. A three-conductor cable with its three-pronged plug is used for operation of the motor with 220 volts.

MOTOR PULLEY AND BELT.—A variable diameter pulley which accommodates a V-type belt is attached to the motor shaft. The inboard flange of the pulley assembly is secured to the end of a bushing which is keyed to the shaft of the motor. The key protrudes through the bushing, forming a track along which the outboard flange of the pulley may slide axially (in and out along the shaft) and yet not slip in a rotational direction. On the end of the bushing a cap is threaded which houses a sleeve-type spacer and a coil spring. The function of this spring is to force the outboard flange towards the opposite fixed flange. Thus, when this pulley is used with its fixed length V-shaped pulley belt, the distance between the motor shaft and the driven pulley shaft may be varied by expanding or contracting the spring-loaded pulley face. This causes the effective diameter of the driving pulley to vary. The endless drive belt connecting the motor and drive pulleys is a combination flat and V-type belt. Maximum friction on the flat-faced pulley is created by transverse serrations on the inner surfaces of the belt.

DRIVE SHAFT ASSEMBLY.—The drive shaft assembly bearings are assembled in the lower right-hand section of the Geneva and clutch brackets. This assembly includes a drive pulley and overload release mechanism, a drive pinion gear, a bevel gear, a retaining collar, and the necessary keys and setscrews to secure them on the drive shaft. The drive pulley is located at the rear of the Geneva bracket and rides free on the drive shaft. The drive pulley is connected to the shaft through an overload release mechanism. This mechanism consists of a release ring, an L-shaped release lever, and a release arm. The release ring is bolted to the bosses of the outer (rear) side of the drive pulley and is mounted so that it encircles and is eccentric to the primary drive shaft. A semicircular notch on one end of the release lever is located on the inside surface at a point on the release ring most distant from the primary shaft. The other end of the release lever is adjacent to the clutch throwout lever.

The release lever is pivoted on a pin through the yoke of the release arm and its roller is retained in the ring notch by two coil springs. This release arm is keyed to the drive shaft and provides a yoke in which to pivot the release lever and an eccentric weight to counterbalance the release mechanism. If a cartridge becomes jammed and overloads the machine (M16), the additional load overcomes the spring tension holding the release lever roller in the ring notch, and forces the roller to ride on the inner face of the release ring. Since the release ring is eccentric to the drive shaft, one end of the L-shaped lever is depressed towards the drive shaft. This causes the opposite end of the lever to move outward contacting the clutch throwout lever, and forcing it to move in a direction that will disengage the clutch.

Forward of and next to the Geneva bracket is a collar which is keyed and retained by a setscrew. This collar positions the shaft longitudinally. The pinion gear is secured to the drive shaft, mounted next to the Geneva bracket, and meshes with the clutch spur gear. A bevel gear is secured to the front end of the drive shaft and meshes with a similar one on the handwheel drive assembly.

HANDWHEEL DRIVE ASSEMBLY.—The handwheel drive assembly is held in place by an auxiliary bracket bolted to the lower right side of the clutch bracket. A transverse shaft with a bevel gear is secured to this shaft and meshes with the bevel gear on the drive shaft. On the outboard end of this shaft may be mounted either a handwheel or handcrank for manual operation of the machine.

CLUTCH SHAFT ASSEMBLY.—This assembly consists of a shaft on which are assembled a clutch assembly, a Geneva crank, a bevel gear, and the necessary securing keys and setscrews. The clutch assembly consists of a slotted, hubbed spur gear, a series of drive and friction disks, a clutch body, an adjusting nut, a nut retainer spring, and a sliding collar. A clutch lever assembly is connected by a rod to the throwout lever. The clutch spur gear rides free on the clutch shaft and is driven by the drive pinion. This spur gear has an extended hub into which has been cut three equally spaced slots.

Six bronze disks and six steel clutch disks are alternately spaced and keyed to the clutch body free of the clutch gear. They are assembled into the slotted hub and ride free on the clutch body. Clearance between the driving and driven disks is adjusted by a knurled nut which rides on a threaded portion of the clutch body. On the rear part of the clutch body, four fingers fit into slots in such a manner that they are enclosed and actuated by the sliding clutch collar. With the collar in the forward position, the fingers compress the friction disk and cause motion of the spur gear to be transmitted through the disk to the clutch body. The clutch body is attached to the clutch drive shaft. With the collar in its rear position, the clutch fingers release the drive disks and allow them to slip, breaking connection between the clutch body and the spur gear. Thus, the motion between the spur gear is no longer transmitted to the clutch shaft assembly. A bevel gear is keyed to the clutch shaft in front of the clutch bracket. This bevel gear is meshed with the crankshaft bevel gear.

GENEVA CRANK.—This crank is located at the rear of the Geneva bracket, and is keyed to the rear end of the clutch shaft. It also mounts a pivoted bearing sleeve on a pin secured to the crank. This crank engages the Geneva cam and imparts intermittent motion to the loading wheel shaft. The part of the clutch shaft which extends beyond the Geneva crank is milled to a semicylindrical shape. The crank arm and the semicylindrical portion of the shaft are positioned so that when the crank engages the Geneva cam wheel, the clutch shaft clears the Geneva cam. With the crank disengaged, the remaining part of the shaft enters into grooves in the Geneva wheel. This action stops its motion to properly position the loading wheel for the next thrust of the pushers.

PUSHER MECHANISMS.—This mechanism is composed of a crank assembly which is powered by the clutch shaft and connected through a link to the reciprocating pusher housing assembly. The pusher crank assembly consists of a shaft supported by two bearings (on the forward face of the clutch bracket) with its axis perpendicular to the clutch shaft and inclined at an angle of 36 degrees to the right of vertical. Mounted on this pusher crankshaft is a bevel gear which meshes with a bevel gear on the clutch shaft, which drives the pusher assembly. This gear and the driving gear on the clutch shaft are marked for proper meshing. Proper meshing insures synchronized timing between the reciprocating pusher mechanism and the intermittent rotation that is transmitted by the Geneva cam and crank to the loading wheel shaft. The pusher crank is keyed to the upper end of the pusher crankshaft and is provided with two holes labeled LINKER and DELINKER. A six-sided steel cam attached by three screws to the pusher crank actuates the link vibrator assembly. The connecting rod is attached by studs to the pusher crank and pusher housing. The pusher crank stud is seated in the proper hole in the pusher crank for linking or delinking operation.

PUSHER HOUSING.—The pusher housing is a bored and bushed cylindrical body which slides on the loading wheel shaft. It also has an attached foot which slides between two supports on the base mount, and twin lugs on the upper side that are bored to take either the cartridge pushers or cartridge ejectors. The pushers are short-shouldered rods threaded at one end and semicircular at the other. The shorter pusher fits into the upper part of the housing, while the longer one fits through the other lug. If the machine is to be used as a delinker, the pushers are replaced by the ejectors. The longer ejector replaces the shorter pusher, and the shorter ejector replaces the longer pusher.

LOADING WHEEL UNIT.—This unit is comprised of cartridge and link positioning sprockets on a shaft that is rotated intermittently by the clutch shaft through the Geneva wheel assembly. The unit consists of link retaining sprockets, a loading wheel, a spur gear, and a Geneva wheel assembly. These components are secured to a shaft extending from the Geneva bracket (at the rear of the machine) to the loading wheel front support. This shaft mounts the Geneva wheel at the rear, the loading wheel and link retaining sprockets at the front, and the spur gear to the rear of the clutch bracket. The shaft is supported by and rotates in the upper bearings of the Geneva and clutch brackets and the loading wheel front support. A portion of the shaft is machined to accommodate the reciprocating pusher housing.

The Geneva wheel assembly is mounted at the rear end of the loading wheel shaft and is powered by the Geneva crank. This wheel assembly consists of a Geneva cam, spacers, a hub, and four bolts with lockwashers. The flange at the rear of the hub has four elongated holes through which the Geneva wheel is secured. To insure adequate clearance between the Geneva crank and the clutch shaft, shims are placed between the hub and the Geneva wheel. This Geneva wheel is a large disk on whose front face are formed ten segmental lugs.

ircular notches on the outer arc of each lug are formed o receive the semicylindrical portion of the clutch shaft. he equally spaced radial grooves formed by the sides f the lugs provide paths in which the Geneva crank ravels.

The loading wheel spur gear which is mounted to the ear of the clutch bracket is keyed to the loading wheel haft. This gear is marked for proper mesh with the mating spur on the feed wheel shaft. The loading wheel assembly is keyed to the forward part of the loading wheel shaft and rotates as a unit. It consists of a cartridge loading wheel, a rear link retaining sprocket, a link loading sprocket, a front link retaining sprocket, and a key which secures these components to the shaft. The cartridge loading wheel is a cylinder with ten equal-y spaced longitudinal grooves formed on the periphery. These grooves take the cartridges and guide them as they are inserted into the links. A radial groove near the front of the cartridge wheel positions the wheel on the shaft with the guide strip attached to the base, riding the groove and rear facings of the wheel. The front and rear link retaining sprockets are grooved to accept the contour of the cartridges but restrict longitudinal movement of the links.

The link loading sprocket is grooved to engage the contour of the links, feed them through the loading point, and out of the machine. The forward link retaining sprocket and the link loading sprocket may be adjusted longitudinally from the rear link sprocket to accept different width links. This adjustment is obtained through the loading wheel front support bearing, which is seated in a threaded sleeve in the front support. A lever attached to this threaded sleeve may be rotated approximately 300 degrees, thus shifting the bearing and spacer forward or aft longitudinally. A spring-loaded pin in the lever handle seats into indexed holes in the front plate, while a stud in the front plate prevents complete rotation of the lever, as previously mentioned above.

FEED ARRANGEMENT.—The ammunition feed unit is mounted on a large cast steel support which is assembled in the right forward part of the machine base. This feed unit contains the feed wheel shaft, feed wheel gear, feed wheel assembly, cartridge guides, link vibrator assembly, and a means for supporting the ammunition tray and link chute assemblies.

The feed wheel shaft is parallel to the loading wheel shaft. At the rear of the ammunition feed unit is the feed wheel spur gear which meshes with the loading wheel spur gear and transmits the rotary motion of the loading wheel shaft to the feed mechanism. The loading wheel and feed wheel spur gears are marked for proper engagement. The feed wheel assembly consists of a pair of ten-toothed sprockets separated by a flanged hub. Three elongated holes in each flange permit alignment of the sprockets assembled to the hub. The assembled feed wheel is positioned directly above the loading wheel. This wheel conveys the cartridges from the gravity feed ammunition trays to the loading wheel.

Two hinged and spring-loaded upper guides and two stationary lower guides retain the cartridges on the feed wheel sprockets. The upper pair of guides fit over the upper guide shaft. Two torsion-type springs fit between the two arc-shaped guides. Tubular spacers provide proper spacing between the sprockets and the spring retaining collars. Spring tension on the guides is developed by rotating the collars against the springs before securing them in place. The lower pair of guides fits over two shafts, is secured in sockets located to the right of the axis of the feed wheel shaft, and is separated by tubular spacers. Protruding forward in the extreme lower part are shafts on which the link chute assembly is mounted.

The gravity feed link chute is a channel-shaped assembly with its outlet and lower end curved slightly inward to deliver the links smoothly to the top of the link loading sprocket. The body of the chute consists f a bottom plate to which a pair of side plates is se-ured. At the flared end of each side plate are two oles near the bottom through which the mounting hafts and a pair of tubular spacers are assembled. A wiveled spacer is placed in holes near the top of these ared ends and serves to separate the sides. Between he bottom plate and the rail insert, rails are mounted hich guide the links through the chutes near a central osition.

VIBRATOR MECHANISM.—This mechanism serves the urpose of shaking the links into mesh as they travel oward the loading wheel. Two vibrator assemblies, ne mounted on either side of the chute, protrude hrough elongated slots in the link chute side plates, nd strike light blows on the sides of the links. A rec-angular steel hammer is secured to the upper end of ach vibrator and protrudes through the link chute lots. The hammer end of the upper vibrator body is pring loaded by a coil spring attached through a hole n the vibrator body. This spring passes under the hute securing to a pin mounted on the opposite side of he chute.

A tie rod holds the vibrators together. Nuts on each nd of the tie rod provide adjustment for the hammer osition of the upper vibrator. This tie rod is attached etween the hammer boss and the bearing boss of the ower vibrator, and is secured to the upper vibrator at he end opposite the hammer. A boss riveted to the ther end of the lower vibrator, provides a socket into which the vibrator rod of the vibrator actuating assembly is seated. This assembly consists of a lever arm pivoted on the feed support while the other end rides the six-sided cam on the pusher crankshaft. The vibrator rod is rounded at one end and rests in the socket of the lower vibrator. At the other end of the rod an end fitting assembles over a stud in the lever. A coiled spring is anchored on studs in the lever and the feed wheel support. The actuating lever cam follower has a roller mounted at one end, and is spring loaded to bear against the cam attached to the crankshaft.

AMMUNITION TRAY.—The ammunition tray feeds cartridges to the feed wheel by gravity. It is a welded unit consisting of a bottom plate, two side plates, two rails, and three mounting brackets. The tray is curved near its lower end to provide smooth feeding of the tapered cartridges. The rails on the bottom of the tray which support the rolling rounds are of unequal height to compensate for the taper of the rounds. A transverse guide plate extends across the top side of the lower ends of the tray. This plate has a warning die stamped on its face. This warning reads:

> "***Warning:*** Do not put rounds into the empty hopper while the machine is running."

The ends of the spring-loaded guides, mounted on the feed wheel support, rest on this guide plate to effect continuous guiding around the feed wheel. A bracket is fastened to the tray at the lower end. This bracket is bored to slide onto the ammunition tray mounting shafts located on the feed wheel support. The outer end of the tray is supported by a rod secured to the tray by a bracket. The other end of this rod is retained in a socket at the base of the machine.

DELINKER ASSEMBLY.—When the M16 link loading machine is set up for operation as a delinker the pushers are replaced by ejectors, the loading wheel linking guide is replaced by a delinking guide, and the feed mechanism is replaced by a loading wheel shield. (See fig. 5–3.) The ejectors are spring-loaded fingers designed to engage the cartridge rim. The short ejector, which is assembled through the upper bushing of the pusher housing, replaces the longer pusher. The long ejector is fitted through the lower bushing, replacing the shorter pusher.

The loading wheel delinking guide assembly includes a group of four segments which guides the disassembled cartridges around the loading wheel to the point of discharge. A latch lever which is pivoted to one of the egments, is used to latch the guide to the loading wheel hield. The delinking guide replaces the linking guide n the loading wheel guide bracket. The loading wheel hield consists of a cast aluminum mounting base to hich is secured a sheet metal shield formed to cover the xposed area of the loading wheel shaft above the ejecors. The base of the shield contains two holes into hich two of the four feed wheel mounting studs fit.

Operation

The M16 20-mm link loading machine is designed for echanical assembly of 20-mm cartridges into linked elts, and to disassemble these belts when desired. The ntermittently rotated feed unit and loading unit convey he cartridges and links through the assembly point and arry the belted ammunition out of the right side of the achine. A reciprocating assembly is coordinated with he loading unit and pushes the rounds into the links n two operations. When the machine is rearranged for elinking operations, the belted ammunition is fed into he left side of the machine. It is then carried by the oading wheel past the reciprocating mechanism, whose ushers have been replaced by ejectors. Fingers on the eciprocating unit (extractors) engage the rounds and xtract them from the links in two operations.

MECHANICAL ACTIONS OF LINKING.—The electric motor, which has a variable diameter pulley secured to the shaft is connected through a flat-type V-belt, and drives the machine at a rate established by the effective circumference to which the variable diameter pulley is adjusted. (See fig. 5–4.) The drive pulley and drive shaft, which are connected through an overload release mechanism, rotate in a counterclockwise direction. The clutch spur gear is driven by the drive pinion which is on the drive shaft. When the clutch lever is in the rear position (the motor end of the machine), it is disengaged and the clutch spur gear rotates freely on the clutch shaft. When the clutch lever is manually changed to the forward position, it moves the sliding collar on

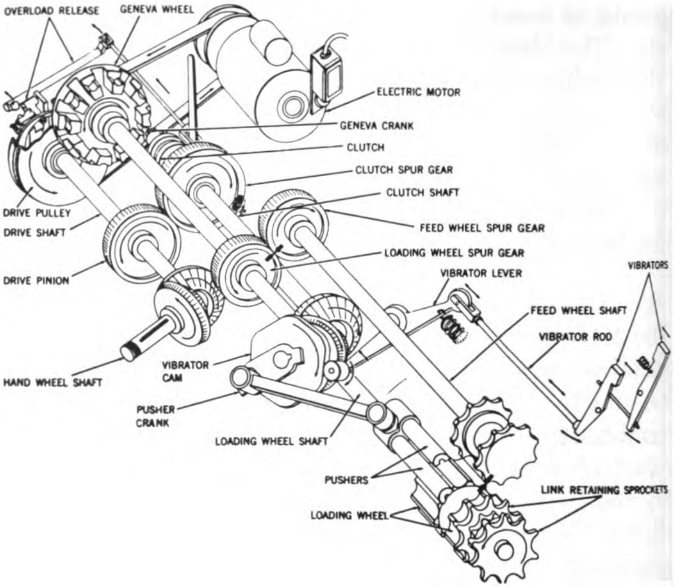
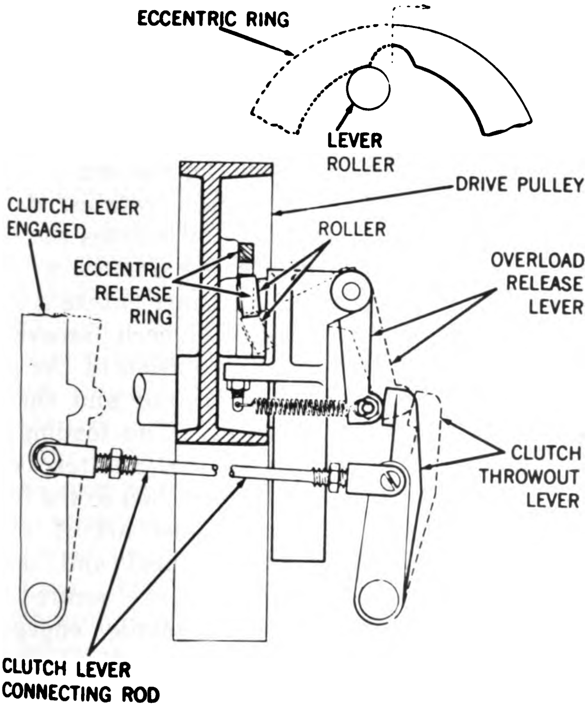


Figure 5–4.—Schematic of M16 link loading machine, arranged for linking.

the clutch assembly forward. This engages the friction clutch through which the clockwise rotary motion of the clutch spur gear is transmitted to the clutch shaft.

The handwheel shaft is connected through a pair of meshing beveled gears to the drive shaft. Rotation of the handwheel counterclockwise imparts a rotary motion through the clutch to the clutch shaft. The overload release mechanism connects the drive pulley to the drive shaft, and functions when an overload occurs on the drive. Such an overload usually results from jammed cartridges or links. The drive shaft and pulley are connected by a spring-loaded release lever which is seated in a notch on the inside of a ring attached to the pulley. (See fig. 5–5.) When an overload occurs, resistance of the shaft overcomes spring pressure on the release lever, forcing the release lever out of the notch. As the pulley and ring continue to rotate, the crescent-shaped cutout of the ring produces an additional movement of the



ADJUST CLUTCH THROWOUT LEVER TO CONTACT RELEASE LEVER WHEN ROLLER IS IN POSITION SHOWN IN INSERT

Figure 5—5.—Overload release mechanism.

release lever which is sufficient to swing the opposite arm against the clutch throwout lever, moving it rearward. The connecting linkage between the clutch lever and the clutch throwout lever causes disengagement of the clutch.

PUSHER MECHANISM.—The crank pusher shaft is connected to the clutch shaft through a pair of bevel gears. These gears are marked to indicate the proper mesh to obtain synchronization between the continually reciprocating pusher mechanism and the intermittently rotating loading wheel unit. A link, which is attached to the pusher crank in an eccentric fashion, is pivoted on the pusher housing. This link converts the clockwise rotary motion of the crankshaft to the reciprocating motion of the pushers. (See fig. 5–3.)

LOADING WHEEL UNIT.—Intermittent rotary motion is imparted to the loading wheel unit through action of its attached Geneva wheel and the Geneva crank attached to the clutch shaft. As the crank rotates, its roller enters a space between the lugs and rotates the Geneva wheel. When the crank clears the Geneva wheel, the semicylindrical end of the clutch shaft enters a circular notch in the outer circumference of each Geneva wheel lug. This latter action prevents rotation of the loading wheel shaft until the notch is cleared and the crank again engages the Geneva wheel. The loading wheel shaft is thereby intermittently rotated counterclockwise.

The cartridge loading wheel is attached to the forward end of the loading wheel shaft, just aft of the link loading sprocket. The loading wheel and the link sprocket rotate as a unit since they are secured to the same shaft. The loading wheel assembly engages the cartridges and links in their grooves and conveys them into alignment with the pushers. The pushers force the cartridges into the links which are restrained by the front and rear retaining sprockets. A link adjusting lever (link selector handle), which is located on the forward end of the machine, is bolted to a threaded sleeve which is retained in the loading wheel front support. When this lever is rotated counterclockwise and set at the position for a particular link width, the threaded bearing holder moves aft, forcing the front link retainer and the link loading sprocket to move toward the cartridge loading wheel. When rotated in a clockwise direction to the position for a wider link, the link adjusting lever causes the threaded sleeve to move forward and permits the front link retainer and link loading sprockets to accommodate the larger width link.

FEED WHEEL ASSEMBLY.—The feed wheel shaft is connected through a pair of spur gears and is coordinated with the intermittent rotary motion of the loading wheel shaft. The feed wheel assembly, secured to the forward end of its shaft as a unit, rotates in a clockwise direction. Rounds are delivered by the gravity feed ammunition tray to the top of the feed wheel assembly. These rounds are engaged by sprockets and retained by guides while being conveyed to the top of the loading wheel.

VIBRATOR MECHANISM.—The pivoted vibrator lever, which is spring loaded against the six-sided cam of the pusher crank, mounts a rod on the arm opposite the cam following roller. The forward end of this rod bears against the pivoted lower vibrator. The reciprocating movement, caused by one arm of the vibrator lever following the irregular contour of the cam, results in movement of the rod. This movement causes the lower vibrator to open and close at a frequency determined by the rotational speed of the pusher crankshaft. The spring-loaded upper vibrator is pivoted and connected to the lower vibrator through a tie rod. Motion of the lower vibrator is transmitted through this tie rod to the upper vibrator, so that they open and close simultaneously.

MECHANICAL ACTIONS OF DELINKING.—The operation of each moving part of the machine when assembled for delinking is shown in figure 5–6. When the machine is assembled for delinking, the feed mechanism is removed, the pusher rods are replaced by ejector fingers, and the pusher connecting rod is connected through the pusher crank into the socket labeled DELINKER.

The reciprocating pusher crank mechanism receives power from the clutch shaft through a pair of bevel gears. With the pusher connecting rods assembled in the socket labeled DELINKER, the pusher housing travels through a shorter reciprocating stroke than for linking. This is due to the shorter radius between the crankshaft and the delinking socket. The spring-loaded fingers now replace the pushers in the pusher housing. They slide over the cartridge case on the forward stroke,

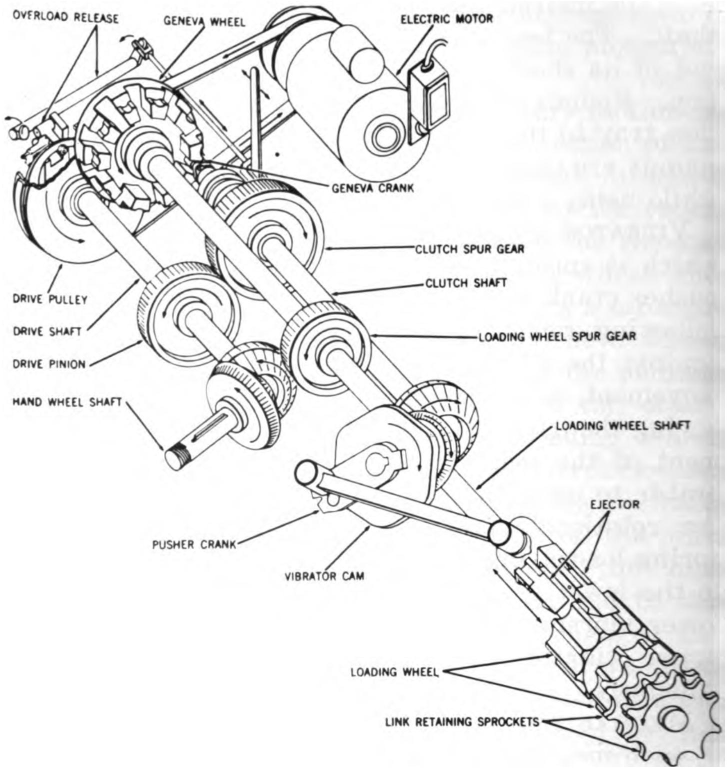


Figure 5–6.—Schematic of M16 link loading machine, arranged for delinking.

engaging the rim of the cartridge, and pulling it rearward out of the link on the return stroke in two steps. The cartridge is first aligned with the long ejector which partially removes the round from the links. On the succeeding stroke of the pusher housing, the round is aligned with the short ejector which completes the removal of the round.

The intermittently rotated loading wheel assembly receives the belted ammunition at the left side of the machine and conveys it past the reciprocating ejector, where it holds the link while the cartridge is being extracted. The components (links and rounds) are then discharged on the right side of the machine.

The M16 link loading machine should be installed in a room where adequate space will minimize hazards to operating personnel. The machine should be placed on a bench not over 30 inches high, and between 20 and 30 inches wide. Containers of loose ammunition and the packaged links should be placed conveniently in order that the loaders will have ready access to the contents without loss of time or motion. The packaged ammunition should be near the loading machine, but in such a position that an inadvertently fired round would not ignite the stored explosive material.

To maintain production and support the loaders of the M16 machine, a minimum of five men is required. At least three of these men are required to feed the machine if tracers are being used. The others are required to open boxes of ammunition and links, supply the loaders, dispose of the linked ammunition, and remove trash and empty containers.

It is suggested that the men detailed to open the cartons place the cartridges in suitable containers holding not more than 300 rounds. For ease in transferring the rounds to the ammunition tray, the cartridges should be placed in the containers with all tips pointing in the same direction. These containers should be arranged conveniently near the ammunition tray. At least two containers of the same type of ammunition should be supplied to the loaders continuously, so that as each container is emptied, it may be replaced by a full one.

ASSEMBLY OF NEW MACHINE FOR LINKING.—Upon receipt of the M16 link loading machine, remove the machine and its components from its shipping container. Inventory the contents against the packing list. Inspect for breaks and obvious damage sustained during shipping or storage. After replacement of any damaged or unserviceable parts, thoroughly clean the machine and its accessories to remove the heavy grease protective coating. The insides of the ammunition tray and link chute should be given special attention so that no sticky accumulation of grease remains to impede the free movement of the cartridges or links. After being thoroughly cleaned, the machine should be lubricated before any attempt is made to operate it.

Since the machine will be only partially assembled upon receipt, the following should be accomplished:

1. Inspect the mesh of the feed wheel spur gears to insure that their index marks are in alignment, and that the feed wheel sprockets align with the grooves in the loading wheel assembly. If, upon inspection, the index marks of these gears are found NOT to coincide, remove the four nuts securing the feed wheel support. Next, free the cam follower of its cam and raise the feed wheel assembly until the spurs are out of mesh. Then rotate the feed wheel, operating the handwheel with clutch engaged until the index marks are positioned for meshing. Retract the cam follower to clear the cam and reassemble the feed wheel unit. Finally, secure the assembly with the four nuts.

2. Inspect the pusher crank connecting rod for proper assembly in the pusher crank socket labeled LINKER. If necessary to move the connecting rod from the DELINKER socket into the LINKER socket, loosen the setscrew in the side of the pusher crank. Remove the pusher crank stud and reassemble through the rod into the socket labeled LINKER. Secure the stud with the setscrew on the edge of the pusher crank. Inspect the pusher mechanism to insure that the short pusher is fitted into the upper part of the pusher housing and the long pusher is assembled through the lower hole.

3. Inspect the overload release lever which should be seated in the notch of the drive pulley ring. If the release lever roller is not seated in the notch of the drive pulley ring, hold the drive pulley and rotate the handwheel until the roller engages the notch in the pulley ring.

4. Assemble the two carrying handles to the rear of the machine base with the cap screws furnished.

5. Assemble the handwheel guard into the hinge on the main cover and secure with the hinge pin packed with the guard.

6. Assemble the motor mounting bracket through the holes in the right rear part of the machine base with the two bolts and nuts provided. Loosen the setscrews in the bottom of the motor table and remove the table bearing pins. Next, assemble the table over the motor mount bracket, insert pins, and secure with setscrews. Finally, insert motor mount table adjustment screws and locknuts in the holes of the motor mount brackets, and adjust the table TOWARD the drive pulley as far as possible.

7. Remove the two screws on the front plate of the motor switch box and then take off the switch plate. Pass the electric motor leads through the switch box mounting plate and attach them to the terminals on the switch. Reassemble the switch mounting plate to the motor and pass the power supply cable through the top of the switch box. Secure the leads to the proper terminals on the switch, and secure the cable with the cable clamp on the top of the switch box. Finally, replace the switch plate and fasten with the two screws.

8. Place the motor on the mounting plate with its pulley facing the rear of the machine. Assemble the drive belt over the motor and drive pulleys with the serrated side inward. Start the motor mounting bolts into the threaded holes in the table through the motor base. Rotate the handwheel with the clutch disengaged, and align the motor so that the pulley belt does not creep toward either side of the drive pulley. Secure the motor firmly. Next, adjust the tilt of the table slightly to the rear with the two adjusting screws which protrude through the motor mount bracket. The tilting motor table is not calibrated to indicate the number of rounds belted per minute. Therefore, it is necessary to run a

test by adjusting the tilt of the table so that a maximum rate of 150 rounds per minute is not exceeded. Compensating adjustments during the test have to be made while the electric motor is STOPPED, and test adjustments should be continued until the desired rate of belting is obtained during a timed interval of one minute.

9. Rotate the manual drive handwheel to move the index mark on the loading wheel spur gear to the uppermost position.

10. Rotate the feed wheel shaft spur gear to bring the index mark into position to mesh with the loading wheel spur gear at the index mark.

11. Retract the vibrator lever cam follower to clear the cam on the pusher crank, and mount the feed wheel unit over the studs on the left side of the machine. Tighten these nuts.

12. Assemble the ammunition tray over the horizontal shaft in the right front side of the feed wheel support, and secure.

13. Secure the ammunition tray support rod to the outer support bracket, and insert lower end of support rod into the socket in the boss at the right front side of the base. Secure with the setscrew.

14. Remove the nuts, washer, and spacers from the two horizontal shafts which protrude forward from the right side of the feed wheel support.

15. Insert spacers between the sides of the link chute in alignment with the mounting holes, assemble the chutes over the shafts. It may be necessary to rotate the feed wheel with the handwheel until the protruding part of the chute base plate clears through the grooves of the loading wheel sprockets.

16. Secure the chute with washers and nuts removed from the shafts, and seat the vibrator rod in the socket at the lower end of the lower vibrator.

17. Retract the spring-loaded plunger at the lower end of the chute and secure with the notch provided on the loading wheel linking guide assembly.

18. Check the type of link being used and adjust the ibrators accordingly.

19. Retract the spring-loaded pin in the link selector ever at the front of the machine, rotate the lever, and eat the pin in the hole appropriate to the type of links eing used.

CONVERTING FROM LINKING TO DELINKING OPERATION.—To rearrange the machine for delinking when it is assembled as a linker, the following procedure is used:

1. Loosen the setscrew holding the ammunition tray upport rod in the socket of the boss at the front of the achine.

2. Loosen the setscrew in the bottom of the ammuniion tray support bracket, and slide the tray and suport rod forward, removing it as a unit.

3. Disengage the spring-loaded plunger on the link hute from the notch of the loading wheel linking guide ssembly. Remove cotter key and washer from the pin n the outer arm of the vibrator lever, and remove the od end and rod.

4. Rotate the latch lever on the forward end of the oading wheel linking guide assembly and remove the nit from the machine.

5. Take off the four nuts securing the feed wheel ssembly support, free the cam follower from the cam n the pusher crankshaft, and raise the feed wheel assembly and the attached link chute to remove the feed wheel from the machine.

6. Remove the nuts and washers which secure the ushers to the pusher housing, and replace the short usher with the long ejector.

7. Remove the long pusher and replace with the short jector. Replace both washers and nuts.

8. Loosen setscrew which secures pusher crank stud n the socket labeled LINKER, remove stud and reassemle through the connecting rod into the socket labeled DELINKER.

9. Assemble the loading wheel shield over two of the

four studs used to secure the feed wheel support and secure with nuts.

10. Remove the loading wheel linking guide from the loading wheel guide mounting stud, and assemble the loading wheel delinking guide on the stud. Insure that the latch is secure in the front of the mounting stud.

11. Adjust the loading wheel for the type of links used in the belt to be disassembled by rotating the link selector lever on the front of the machine to the proper position for the type of link concerned.

12. As a final check on the above conversion, manually operate the machine by the handwheel through one or more complete cycles. Then disengage the clutch, start the electric motor, reengage the clutch, and run the machine to check it for proper functioning.

AMMUNITION AND LINK FEEDING.—If the M16 link loading machine has not been inspected for proper functioning prior to commencement of linking operations, manually operate the machine through a few complete cycles to insure no binding occurs. Then start the electric motor and engage the clutch smoothly to run the machine empty several complete cycles. Check for proper functioning of all parts, disengage the clutch, and stop the motor by turning off the switch.

Load the links into the link chute with the open sides up. THE LINKS MUST BE LOADED WITH THE SINGLE LOOPS INSERTED INTO THE CHUTE FIRST FOR ASSEMBLY OF RIGHT-HAND BELTS, AND WITH THE SINGLE LOOPS TRAILING FOR ASSEMBLY OF LEFT-HAND BELTS. Place the ammunition into the ammunition loading tray with all tips pointing toward the forward end of the machine, with the base of the round toward the pushers.

Depending on the tactic involved, tracer, incendiary, and/or armor piercing rounds will be arranged in the loading trays in specified sequences. A dummy round may be inserted between certain rounds of the ammunition being loaded to designate the end of a belt. This dummy round is removed later to separate the different belts.

In order to get the ammunition started into the ma-
ine, operate the machine manually with clutch en-
ged until one round is completely inserted into its
ks. Then disengage the clutch, start the electric mo-
r, reengage the clutch, and continue the operation.
hen the required number of belts are made up, stop
e machine by disengaging the clutch and placing the
ectric motor switch in the OFF position. Remove all
unds and links remaining in the machine.

OVERLOADS OR JAMS.—If an overload of sufficient force
curs to cause the overload release mechanism to dis-
gage the clutch while linking or delinking, stop the
ectric motor. Remove the main cover and reseat the
erload release lever roller in the notch of the pulley
ng as previously described. (See fig. 5–5.) Deter-
ine the cause of the overload and remove any objects
using obstruction to free movement of any of the mov-
g parts. After the cause of the stoppage has been
cated and removed, engage the clutch smoothly and
erate the machine manually to assure free operation
all working parts of the machine. Then replace the
ain cover and continue operation.

LUBRICATION.—The frequency of lubrication required
any machinery is largely dependent on the extent of
s use. When the M16 link loading machine is in con-
ant use, it requires lubrication for each eight hours of
peration. Naturally, if this machine is used intermit-
ntly, it requires proportionately less lubrication. How-
ver, the interval between lubrications should not ex-
ed ten hours even during intermittent operation. For
roper lubrication on this machine, reference should be
ade to the Ordnance Pamphlet concerned. This pub-
cation will give all data pertinent to the correct lubri-
ants to be used, as well as the lubrication points, and
ethods of application.

A pressure oil gun is packed with the equipment for
se at points equipped with pressure fittings. An oil can
provided for use on those parts which do not incorpo-
ate pressure fittings, such as the vibrator mechanism;

the pusher slides and supports; the clutch shifter groove; the Geneva crank roller; the Geneva wheel grooves and locking segments; and the overload release and clutch throwout mechanisms. Stop the electric motor before removing the main cover to lubricate. A thin film of oil should be maintained on all gear teeth. The electric motor has sleeve bearings which are lubricated by oil saturated wicks. Apply ONLY ten drops of oil to these wicks for each month of continuous operation. The ball bearing at the front of the loading wheel shaft is packed in grease at the factory and requires no lubrication except at the overhaul period.

CLEANING.—A coating of rust preventive compound, or grease, is applied to the M16 link loading machine before shipment or storage. This coating should be removed completely through the use of a dry cleaning solvent before the machine is put in operation. The machine should be allowed to dry after cleaning and then properly lubricated. Also, if the machine has been idle for any appreciable length of time, it should be thoroughly cleaned and oiled before being put into operation. However, before attempting to oil the sleeve bearings in the electric motor, insure that the oiling wick actually needs lubrication. The parts or surfaces which come in contact with either the links or cartridges during the operation of the machine should be cleaned as frequently as necessary to prevent dirt and/or gummy accumulations which might impede free flow of the rounds and links.

PARTS REPLACEMENT.—Disassembly of the machine is not difficult. However, parts should be carefully identified as they are removed. Disassembly should not be attempted prior to a careful study of the Ordnance Pamphlet prepared for this machine. The Ordnance Pamphlet shows detailed instructions for parts replacement, and in addition contains a parts list affording graphic exploded views and identifying numbers of all the component parts of the M16 link loading machine.

ADJUSTMENTS.—From time to time, it will be necessary to make various adjustments to the M16 machine. Although it is necessary to obtain and study the Ordnance Pamphlet covering this machine in order to properly make any adjustments, a general idea of the most commonly made adjustments is furnished in table 5–1.

Table 5–1.—M16 link loading machine adjustments.

Adjustment	Instruction
Overload release mechanism adjustment. (See fig. 5–5.)	1. Loosen the locknuts on clutch lever connecting rod. 2. Rotate connecting rod several turns to lengthen the linkage. 3. Manually depress the release lever to free the roller from the notch. 4. Rotate drive pulley slightly so that the roller rests at the edge of the notch. 5. Engage the clutch. 6. Rotate connecting rod until clutch throwout lever just touches the overload release lever. 7. Tighten locknuts.
Machine speed adjustment. (See fig. 5–7.)	1. Disconnect electric cable from outlet. 2. Remove main guard cover. 3. Tilt the motor table toward the drive pulley to increase speed, or away from drive pulley to decrease speed of the machine by adjustment of the screws in the motor mount bracket. 4. Rotate the pulley by hand until the belt has adjusted itself to the change. 5. Replace guard cover and connect cable to the outlet. 6. To check the speed, run the machine for a definite length of time and count the number of rounds linked or delinked, converting this number to rounds per minute.

Table 5–1.—M16 link loading machine adjustments—Continued

Adjustment	Instruction
Clutch adjustment. (See fig. 5–8.)	1. Disconnect the electric motor cable and remove main guard cover. 2. Raise end of locking spring that protrudes through the knurled adjusting ring. 3. Turn knurled adjusting ring counterclockwise several turns so that clutch slips. 4. Engage clutch.

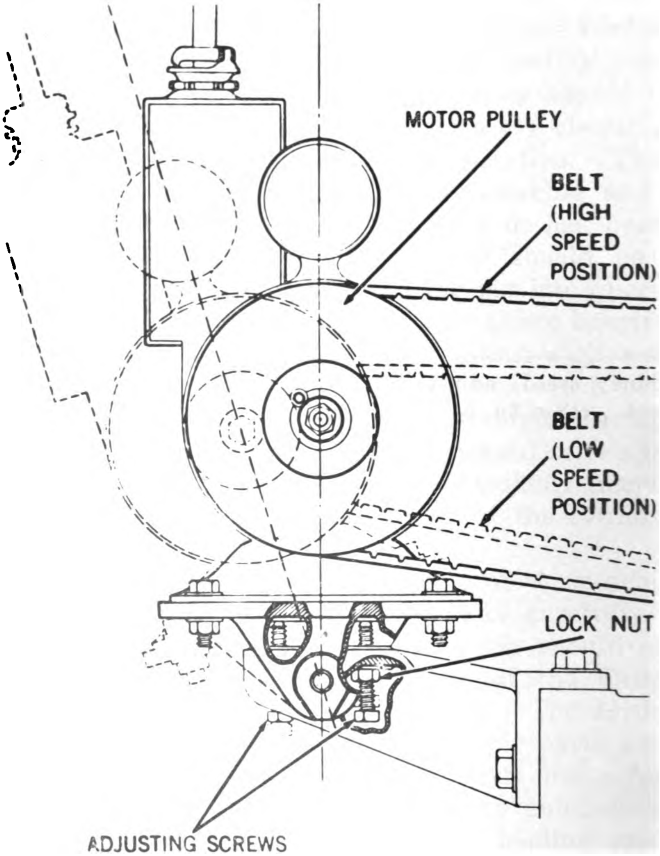


Figure 5–7.—Machine speed adjustment.

Table 5–1.—M16 link loading machine adjustments—Continued

Adjustment	Instruction
lutch adjustment. (See fig. 5–8.)—Con.	5. Hold pusher crank from turning and operate machine by handcrank. 6. While manually turning handcrank with pusher crank held firmly, turn adjusting ring clockwise until overload release lever disengages clutch. 7. Turn adjusting ring clockwise an additional ⅛ turn. 8. Continue clockwise rotation of adjusting ring until locking spring seats in slotted collar.

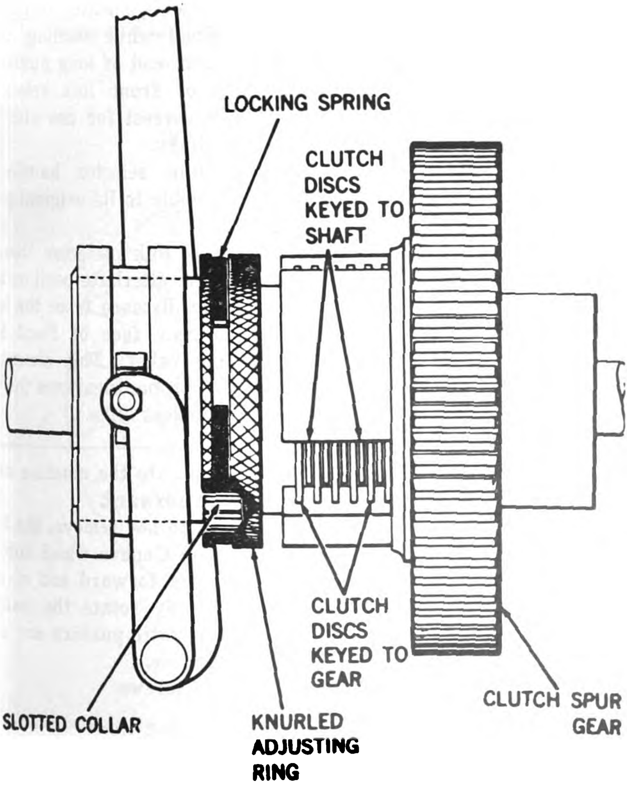


Figure 5–8.—Clutch adjustment.

Table 5–1.—M16 link loading machine adjustments—Continued

Adjustment	Instruction
Loading wheel shaft longitudinal adjustment. (See fig. 5–9.)	1. Verify that all cartridges and links are removed from the machine. 2. Latch the link selector handle in the position marked M3 or M8, depending on the width of the links being used. 3. Manually operate the machine to move the pushers to their forward position. 4. Remove four screws securing link selector handle and remove handle. 5. Turn adjusting screw clockwise or counterclockwise, pushing or pulling loading wheel while turning, until distance from end of long pusher to rear face of front link retaining sprocket is correct for use with the narrowest links. 6. Reinstall link selector handle as near as possible to its original position. 7. Rotate the link selector handle around to the alternate position and measure the distance from the long pusher to rear face of front link retaining sprocket. This dimension should give proper clearance for the use of the widest links.
Loading wheel rotational adjustment. (See fig. 5–10.)	1. Manually operate the machine until pushers are forward. 2. Loosen, but do not remove, the four cap screws in Geneva wheel hub. 3. Sighting from forward end of machine, manually rotate the loading wheel shaft until pushers are centered in grooves. 4. Tighten cap screws.

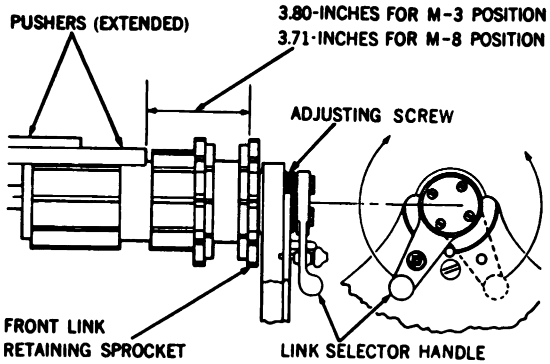


Figure 5—9.—Loading wheel shaft longitudinal adjustment.

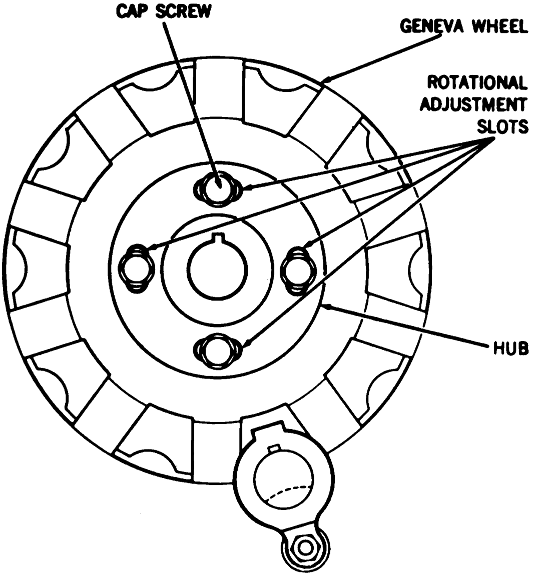


Figure 5—10.—Loading wheel rotational adjustment.

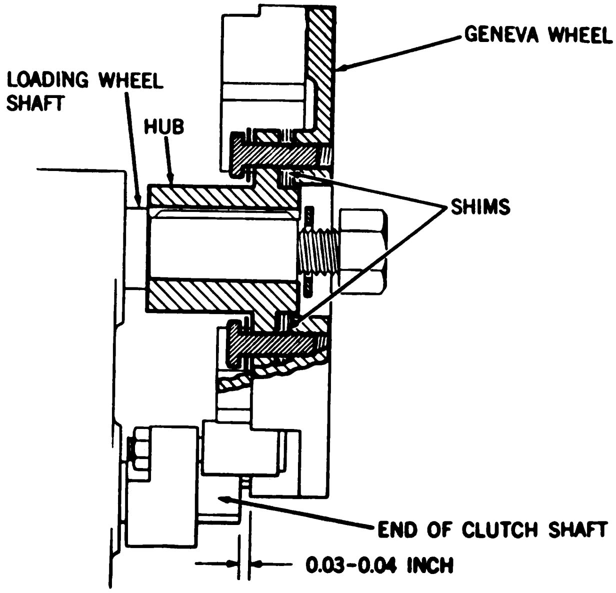


Figure 5–11.—Loading wheel shaft Geneva wheel clearance adjustment.

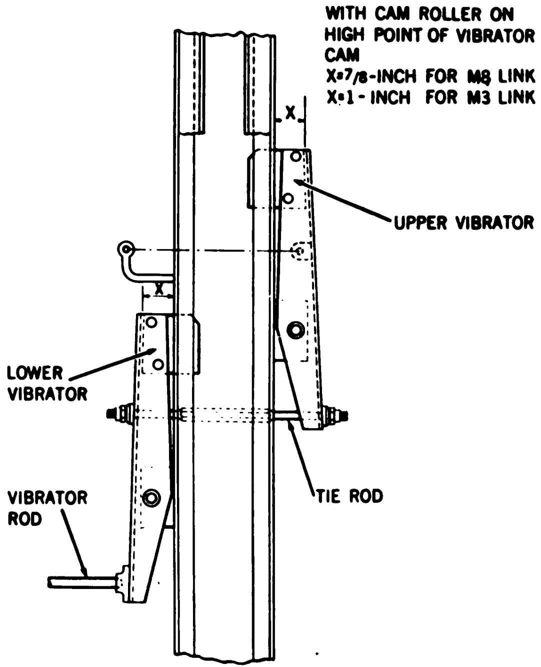


Figure 5–12.—Vibrator adjustment.

Table 5–1.—M16 link loading machine adjustments—Continued

Adjustment	Instruction
Loading wheel shaft Geneva wheel clearance adjustment. (See fig. 5–11.)	1. Longitudinal clearance between the Geneva wheel and Geneva crank is obtained by assembling a suitable number of 0.01-inch shims between the wheel and its hub. 2. Removal or addition of these shims is not required for operational adjustment of this machine. 3. If this machine is disassembled, care must be taken to preserve and replace the shims on reassembly. 4. Different numbers of shims may be required to obtain correct clearance when a loading wheel shaft or clutch shaft requires replacement. 5. After making this adjustment, check loading wheel shaft longitudinal and rotational adjustments. Readjust, if necessary, as outlined in the two preceding adjustment sections.
Vibrator adjustment. (See fig. 5–12.)	1. Remove main guard cover. 2. Engage clutch and operate machine manually until vibrator cam roller is on high point of vibrator cam. 3. Loosen vibrator rod locknut. 4. Turn vibrator rod until a measurement of one inch exists between the side plate of the link chute and the rear face of the lower vibrator hammer. 5. Tighten vibrator rod locknut. 6. Loosen tie rod locknuts. 7. Rotate tie rod sufficiently to obtain a 1-inch measurement between the side of the link chute and the rear face of the upper hammer. 8. Tighten tie rod locknuts.

Table 5–1.—M16 link loading machine adjustments—Continued

Adjustment	Instruction
Vibrator adjustment. (See fig. 5–12.)—Con.	9. Steps one through eight contain adjustments of the vibrators for the narrow links. To adjust for the wide links, repeat steps one through five, substituting ⅞ inch for the 1-inch dimension in step four. Correct adjustment of the vibrator rod adjusts both vibrator hammers.

SAFETY PRECAUTIONS

Operating the M16 link loading machine involves certain hazards to the operating personnel as well as possible material damage. Operating personnel should be aware of these dangers and understand how to prevent dangerous situations from arising during linking, delinking, and machine maintenance work. Listed below are some of the more generally indicated safety precautions:

1. Carefully check the machine and all the components to insure that it has been properly cleaned of preservatives and lubricated in accordance with the latest directive written for this machine.

2. In the event the machine has been disassembled, check the mesh of the bevel gears connecting the intermediate and pusher crankshafts during assembly.

3. Check to insure that the roller of the overload release lever is properly seated in the notch of the drive pulley ring.

4. Manually operate the mechanism by rotating the handwheel in a counterclockwise direction, checking all the while to insure that the working parts function without interference. Also, check the pushers and/or the ejectors, of the reciprocating mechanism for alignment with their respective grooves in the loading wheel assembly.

5. Prior to operation of this machine, insure that the clutch is disengaged, start the electric motor, and engage the clutch smoothly. Allow the machine to operate for a while to insure that it is functioning properly.

6. Do not carry out linking or delinking operations with the main cover guard removed.

7. In the event of a jam while linking or delinking, stop the electric motor, disengage the clutch, and remove the cause of the stoppage before restarting the motor.

8. To make belting speed adjustments, always stop the motor first, and then make the necessary adjustments while operating the pulleys by hand, until the belt has adjusted itself to the change.

9. Insert the links into the chute with their open sides upward and feed the links continually into the chute, with the single loop leading for the right-hand belts, and the double loop leading for the left-hand belts.

10. Cartridges will be placed in the tray with their tips pointing towards the front of the machine.

11. Observe the warning on the plate attached to the lower end of the ammunition tray, which reads, "***Warning:*** Do not put rounds into empty hopper while machine is running."

12. Always keep the ammunition tray and link chute as nearly full as possible during operations. Stop the machine before the last few cartridges are out of the ammunition tray, or before the links fall below the level of the lower vibrator hammer.

13. Before starting operation of the machine, and while the loading wheel is still empty, manually rotate the loading wheel until the first round joins a link and the linking process has begun.

14. When making adjustments to or giving instructions on the M16 machine always use dummy ammunition.

15. Smoking or introduction of any types of flame producing articles shall never be permitted in or near the belting area.

16. All measures for prevention of fires shall be exercised in the areas where belting is in progress.

17. Safety devices provided for the handling of ammunition shall always be used.

18. No ammunition shall be broken down or tampered with, nor will it be fired in any device or gun not specifically designed for that particular ammunition.

19. Every precaution shall be taken to prevent ammunition from falling into unauthorized hands, such as those of souvenir hunters.

20. Areas containing explosives shall be adequately guarded at all times.

21. When conducting operations with or handling any ammunition or explosives, the current applicable instructions shall be consulted and strictly complied with.

22. An officer, or petty officer trained in handling, storing, and loading of ammunition or explosives shall always be in charge of the personnel performing these tasks.

23. Before commencing linking or delinking operations, insure that the pushers or ejectors are properly installed and secured.

24. Ammunition shall always be handled with care.

25. When in doubt as to the exact meaning or significance of any safety order, an interpretation of this order shall be requested from the Bureau of Ordnance through channels.

QUIZ

1. Before starting the M16 link loading machine, filling the empty loading wheel with ammunition is accomplished by
   a. electrically operating the machine
   b. manually operating the machine
   c. electrically and manually operating the machine
   d. none of the above

2. No linking or delinking operations are to be carried out without
   a. the clutch properly adjusted
   b. the speed properly adjusted
   c. the main cover guard installed
   d. all of the above

3. Intermittent rotary motion of the loading wheel is received from the
   a. clutch
   b. feed wheel
   c. Geneva wheel
   d. drive wheel

4. The speed at which the machine will link or delink ammunition is controlled by the
   a. tilt of the drive motor
   b. type of links being used
   c. type of drive belt being used
   d. overload mechanism

5. The M16 machine will belt ammunition at a rate of how many rounds per minute?
   a. 150 to 200
   b. 85 to 250
   c. 85 to 150
   d. 50 to 150

6. The M16 machine set up for delinking will operate at a speed of how many rounds per minute?
   a. 50 to 150
   b. 85 to 250
   c. 85 to 150
   d. 150 to 200

7. Operated manually, the machine can belt an average of how many rounds per minute?
   a. 60
   b. 85
   c. 150
   d. 250

8. When operating the machine electrically, the handcrank is
   a. left in position on the machine
   b. replaced by a protecting nut
   c. replaced by the handwheel
   d. removed but not replaced by another item

9. In the event of a jam, the overload release mechanism will disengage the
   a. drive shaft from the drive pulley
   b. clutch from the Geneva crank
   c. clutch automatically
   d. loading wheel shaft from the clutch shaft

10. To reset the overload release after a jam,
    a. vary adjusting screws on the motor base
    b. adjust the clutch lever connecting rod
    c. turn the handwheel while the motor is stopped
    d. turn the adjusting ring clockwise

11. With the clutch engaged, constant rotary motion is changed to intermittent rotary motion by the
    a. Geneva wheel
    b. Geneva crank
    c. clutch
    d. drive gear

12. With the machine set up for delinking, the first round in the belt is positioned first in front of the
    a. short ejector
    b. long ejector
    c. short pusher
    d. long pusher

13. Rotary motion is changed to reciprocating motion and transmitted to the pushers or ejectors by the
    a. clutch
    b. pusher crank
    c. vibrator cam
    d. Geneva crank

4. To maintain production and support the loaders while linking, the minimum crewmen required is
    a. 3
    b. 5
    c. 8
    d. 11

5. When the machine is used frequently for only short periods, the time between lubrications should not exceed how many hours?
    a. 8
    b. 10
    c. 15
    d. 30

6. When converting the machine for use in delinking, replace the
    a. short pusher with a short ejector
    b. long pusher with a short ejector
    c. long pusher with a long ejector
    d. short ejector with a long pusher

CHAPTER 6

AIRCRAFT TURRET SYSTEMS

Soon after the early experiments which involved shooting guns from aircraft were commenced, it became apparent that the gunners would have increasing difficulties in accurately firing their guns. This was mainly due to the increasing wind pressure on their bodies as the top speeds of their aircraft became higher and higher as time went by. The first aircraft gun turrets were designed primarily to get the gunners out of the slipstream and to give them vastly increased accuracy of fire by making the turret do most of the mechanica work of gun laying. In being able to concentrate on tracking the target mechanically and not having to fight terrific wind pressures, the operator was in a much better position to make his fire count. The British proved this conclusively at the evacuation of Dunkirk when their turret equipped aircraft scored a decisive victory over the Luftwaffe without the loss of a single aircraft due to enemy action.

World War II witnessed the speedup of design and production of the aircraft turret as well as its invention. Design and methods of powering the turret became the major problems associated with this new weapon. Today, aircraft turrets are basically separated into types, such as tail, nose, waist, and upper deck turrets. The design of each is peculiar to its location within the aircraft and the purposes for which it is used. There are currently only two methods of powering the aircraft turret: electric drive and electrohydraulic drive. Refinements to the turret have been eagerly dreamed up,

anned, drawn, produced, and tested in combat. The
ght units of the turret have progressed in design and
efulness from the early illuminated fixed sights, with
hich the gunner had to establish by estimation the
oper lead necessary to hit the target, to the present
y lead-computing sights, which are interconnected to
e radar equipment for automatically computing lead,
acking, and firing on seen or unseen targets.

This chapter deals with the function and operation of
e aircraft turret, its component parts, and circuitry
general, but does not go into the detailed characteris-
s and physical makeup of the several components
hich constitute the turret. The Chief and First Class
viation Ordnancemen need to have a broad knowledge
the aircraft turret in order to actually train those
ider them in the correct and efficient maintenance and
pair of the turret. This knowledge will come only
rough a thorough understanding of the function, op-
ation, and general upkeep of the turret itself. As
ith many other things, it is not necessary, nor is it
sirable, to commit to memory such detailed matters
clearances between certain working parts of the tur-
t. The important things to remember are: (1) there
ust be certain clearances between these parts and (2)
e reasons for their existence. Reference to the per-
ient publications will quickly offer the correct clear-
ices when and where this information is needed.

The aircraft turret of today has become such a com-
ex unit that its replacement, upkeep, and repair is
coming more and more a responsibility divided be-
een several aviation rates rather than remaining al-
ost wholly the responsibility of the Aviation Ordnance-
an. However, the wise ordnanceman will learn as
uch as possible about the units associated with the
rret, such as radar and other equipment, and will not
op learning upon complete familiarization with those
iits and areas of work to which he is specifically as-
gned. He knows that the best qualified men are those
ho have the broadest knowledge of the areas associ-

ated with aviation ordnance, in addition to those area of aviation ordnance specifically assigned.

Both the electric drive and electrohydraulic turret will be discussed in this chapter. Therefore, it will b necessary for the First Class and Chief Aviation Ordnanceman to understand how these turrets function, an the procedures for general maintenance work and routine checks.

As a first class and chief petty officer, you will b teaching as well as learning, with the heavier responsibilities lying with instructing and wide supervision o those under you in all phases of aircraft turret work As a third class and striker, you were shown how th turret worked in much detail. As you advanced in rat your actual detailed work on the turret became less an less, and you gained more in the theoretical aspects o the work. Later, your actual work with the turret became more a matter of demonstrations and explanation of the turret to those under your instruction. You ma not now remember that a specific resistor has a capacit of 75 ohms, but quite likely you will be able to kno from the indicated troubles with a turret that a resisto in a certain circuit is the component causing the trouble You spotted this trouble without difficulty due to you experience and technical knowledge of the turret system. You are now qualified to pass this information and much more like it, along to those under you so tha they will be able to correct the difficulties.

ELECTRIC DRIVE TURRET SYSTEM

Theory of Operation

The operation of the electric drive turret may be considered to commence with actuation of the turret maste switch. Closing this switch supplies current to the major components of the turret as well as to those which are auxiliary in nature to the turret drive system. Afte the master switch has been energized, the action switches may be closed, except in certain installations when a warmup period has to be observed. Closing the action switches releases the drive motor brakes (where installed) and furnishes current to the fields of the turret drive motors as well as to the turret controller.

The controller may have associated with it, in various installations, the microphone switches, a coordinatng feature for searchlight manipulation, the trigger switches, and the bombsight arming switch. In displacng the controller handles from their neutral or "zero" setting, horizontal displacements give movements in azimuth, vertical displacements give movements in elevation and depression, and diagonal displacements in any direction give a combination of the two movements. The motor-generator unit produces power in the amounts required by the displacements of the controller handles. This controlled variable power runs the azimuth and elevation drive motors at speeds directly proportional to the amount of displacement, or deflection, of the controller handles. Limiting stops for the turret and interrupters are installed on and in the turret to prevent it from rotating too far in azimuth and elevation and the guns from shooting into structural members of the aircraft, thereby doing damage to the aircraft and turret.

Several sights and sight combinations are used in the various electric drive turrets. Their major function is to compute the lead necessary for hitting the target. However, they may be used for other purposes, such as in conjunction with the stabilization gear which maintains the turret on an even keel for actuation of the fire control. The guns employed in aircraft turrets are currently either .50 caliber or 20-mm. They are charged either by pneumatic pressure or manually, use either percussion ammunition or electrically primed (20-mm only) ammunition, and may fire either in synchronization or free. The ammunition for these guns is ordinarily fed from cans (either built-in or removable) through flexible chuting to the guns. Ammunition boosters may or may not be used as aids in getting the ammunition to the guns.

The gun cameras and gunsight recording cameras are electrically connected with the gunfiring system and the ranging mechanism where fire control systems are installed so that they operate while the guns are being fired, or during ranging while tracking. The gun camera is a motion picture unit, while the gunsight recording camera is basically a still picture unit. One takes continuous movies, and the other takes timed interval still pictures through the illuminated gunsight.

Manual operation of the electric drive turret is carried out through handcranks and clutch arrangement. Action of the handcranks disengages the turret drive motors by releasing a clutch mechanism through which the elevation and azimuth drive motors are connected to the gear sectors of the turret. The turret may then be operated by engaging and turning the manual cranks when it is desired to return the turret to its neutral azimuth and elevation position, moving the turret while boresighting, while testing the actions of the turret throughout all its movements, and while checking the turret during maintenance work. Turrets are designed so that they may be operated manually. There is generally a foot-actuated trigger switch associated with this installation which allows the gunner to fire the guns while tracking manually.

The physical location of the turret within the aircraft determines the type, installation method, and mode of attachment to the aircraft. There are upper deck turrets, tail turrets, nose turrets, and waist (teardrop) turrets. Turrets have even been recessed into the bottom of the aircraft. They were extended mechanically below the fuselage to reach their firing positions. However, this type, along with the waist turret, has more or less been discarded. Generally speaking, turrets are either able to rotate in azimuth in an unrestricted manner, or to a restricted number of degrees. Movements in elevation are necessarily restricted in all types due to design features of both the aircraft and turret, and to the lack of necessity of their training either vertically upward or downward.

Azimuthal movements of the turret are possibly due to the fact that the turret is supported by a track or bearing trunnion assembly. Elevation movements of the turret are performed on gimbals (cradles) or a vertically located set of bearings in mating races. The outer races are secured to the upper and lower trunnions and the inner race mounts the turret ball and parts. For elevation movements, the ball itself rotates in a vertical plane inside the outer race secured to the trunnions, or by the guns riding in gimbals (cradles). These gimbals are elevated and depressed while the turret is restrained from these movements.

Theory of Lead Computation

Computation of lead is derived by resolving the lead which is necessary to hit the target into two factors. The first is the lead necessarily arising from the relative motion between the firing aircraft and the target, or the KINEMATIC LEAD. The second is the BALLISTIC LEAD (sometimes called gravity lead) which comprises all the ballistic factors of the gun, ammunition, gravity, etc. The lead-computing sights currently in use compute the kinematic lead from the angular velocity with which the gunner tracks the target as well as from the range he determines, and then combines the results obtained with an appropriate ballistic deflection or lead.

Kinematic lead is that portion of the displacement of the gun line (axis of the gun bore) from a direct line of sight to the target which is necessary to compensate for the effects of relative motion between the aircraft and its target. To be specific, it is the angle proportional to the angular velocity (rate of turn) of the aircraft multiplied by the time of flight of the projectile. The rate of turn, which is the first factor of kinematic lead, is supplied to the gyroscope in the sight unit. When tracking a moving target, the pilot flies a balanced (coordinated) turn. In such a turn the gyroscope of the sight unit is offset from its zero position by the aircraft's angular velocity. Time of flight of the projectile is the second factor of kinematic lead. This factor is fed to the sight unit by a computer. This computer supplies a current to the range coils of the sight unit, the effect of which limits the offset of the gyroscope in proportion to the magnitude of the current. As the target range decreases, the limiting current to the range coils on the sight unit INCREASES. Thus, in a constant rate turn, as the range to the target decreases, the kinematic portion of the computed lead DECREASES.

The other component of gun line displacement from a direct line of sight to the target is the ballistic lead. This lead is the angular offset of the gun datum line vertical from the target, which is necessary to compensate for the gravity drop of the projectile during its flight to the target. Ballistic lead is proportional to the projectile's time of flight divided by the projectile's average velocity. Average velocity is the muzzle velocity of the guns less the losses from air drag or resistance. Time of flight is computed through a consideration of range, range rate, and average velocity of the projectile. The radar interconnected to the system computes a voltage proportional to the range and sends this information to the computers. The changes in range rate are supplied by one of these computers to the other one. The airspeed of the aircraft is manually set into one of the computers by a switch. The ballistic constants of the ammunition being used are supplied by a ballistic unit in the computer. The average velocity computed from all these factors introduced by the computers determines the time of flight of the projectile and the ballistic lead.

The ballistic lead is then acted upon by an accelerometer in one of the computers which modifies the computations to compensate for the forces of gravity acting on the aircraft while in the turn or maneuver. This compensation depresses the image formed by the gyroscope on the sight unit reflector to give the correct ballistic lead angle. Thus, it may be seen that the difference between these two angles, or sight lines, becomes the LEAD ANGLE. In operating the lead-computing sight, the operator maneuvers the turret so as to keep the gyroscopic reticle image (pipper) on the target. In so doing, he automatically displaces the line of sight from the gun bore line by an amount which is the proper lead angle.

Operation of Turret Components

Power to the electric drive turret is supplied by the aircraft's electrical system. Generators driven by the aircraft's engine(s) supply both 28-volt d.c. and 115-volt a.c. (400 cycle) to the turret. The 28-volt current is supplied from the aircraft's regular generator(s). The 115-volt current is supplied by either a special generator driven by the engine(s) or by an inverter in the aircraft's electrical system. Electrical power to the turret is led through an emergency switch outside the turret. There are many reasons for installing such a switch. The turret operator may be injured and not able to return the turret to its neutral position. A crew member may easily cut off all power to the turret from outside and return the turret to its neutral position manually so that first aid might be rendered to the operator and/or prevent the turret from operating wildly due to some mechanical malfunction. Turret installations are normally designed so that action of the turret is automatically stopped in the event that the operator's hands fall from the spring-loaded action switches.

ELECTRICAL SYSTEMS.—Power for operation of the electric drive turret enters in either of two manners, through a cable or through a system of sliprings. Turrets which are restricted by nature of their locations and uses to a limited number of degrees of azimuthal rotation get their power through a cable arrangement. Nose and tail turrets fall into this category. Those turrets which are unrestricted in rotation, such as the upper deck turrets, normally receive their power through a slipring arrangement. Power from the aircraft is routed to the electrical distribution boxes within the turret. There may be only one or there may be more of these boxes depending on the installation and the power distribution necessary. These boxes are commonly called JUNCTION BOXES.

Power to the master switch of the turret closes the master relay. There are, however, numerous individual devices and components of the turret which derive their power from separate circuits which bypass the master switch and relay. This power is then supplied to the following turret components which are normally found in electric drive turrets: motor-generator, turret drive motor fields, the controller, drive motor brakes, action switches, structural interrupters, gunsight, suit heater, circuit breakers, indicator lights, trouble lights, gunfire interrupter, gun camera, gun camera heater, radio noise filter, intercommunications system, turret ventilation system, and the guns.

Individual differences between electric drive turrets usually stem from the fact that each manufacturer adds refinements in the form of additional circuits so that his particular turret will perform special functions for the aircraft for which it was designed. There are numerous individual devices and components of the turret which derive their power either from the master armament switch relay, or from separate circuits which bypass the master switch and relay. However, none of these components will be found in ALL types of electric turrets. Some of these components are: stabilization gear, searchlight, pneumatic compressor, aircraft fire control system, radar, inverter, transformer (for electric primed ammunition), voltage regulator, time delay relay, gun camera and CG–4 camera, taillights, ammunition boosters, transmitters, limit switches, boresight switches, and receivers.

The stabilization system incorporates an inverter to give it the proper voltage for operation, whereas some gun circuits have transformers for the electric primed ammunition.

The various circuits of the aircraft turret are protected from overloads by circuit breakers which are strategically placed within these circuits. Certain of these circuits are included for the sole purpose of providing safety for the operator, the turret, and the aircraft. Gunfire interrupters protect the aircraft, structural interrupters and limit switches protect the turret and aircraft, etc. Quite often these features serve more than one function in their overall operation, however. The various components of the turret are electrically connected by wires and cables which are fitted with cannon-type connectors for ease of removal and installation of the components. Replacement of the turret itself is aided by these same type connectors.

Figures 6–1, 6–2, 6–3 and 6–4 should be consulted as a unit during study of the turret component operation section in order that all components discussed may be identified.

POWER TO THE ELECTRIC DRIVE turret is made available to the aircraft's 28-volt main power bus from the batteries or generators through the battery relay and switch, the turret emergency switch, and the radio noise filter. (See fig. 6–1.) The BATTERY RELAY is placed in the circuit in order that the pilot may control the heavy current to the aircraft main power bus by remotely opening and closing the battery switch. From the MAIN POWER BUS the power is furnished to the turret through the EMERGENCY SWITCH. This switch, located outside the turret, is designed for high amperage loads, and is employed for shutting down power to the turret in the event of a malfunction or electrical failure within the turret. From the emergency switch the power is fed to the turret through a power brush assembly, or a cable in turrets in which azimuthal rotation is necessarily restricted to small arcs of gunfire. These brushes transfer power

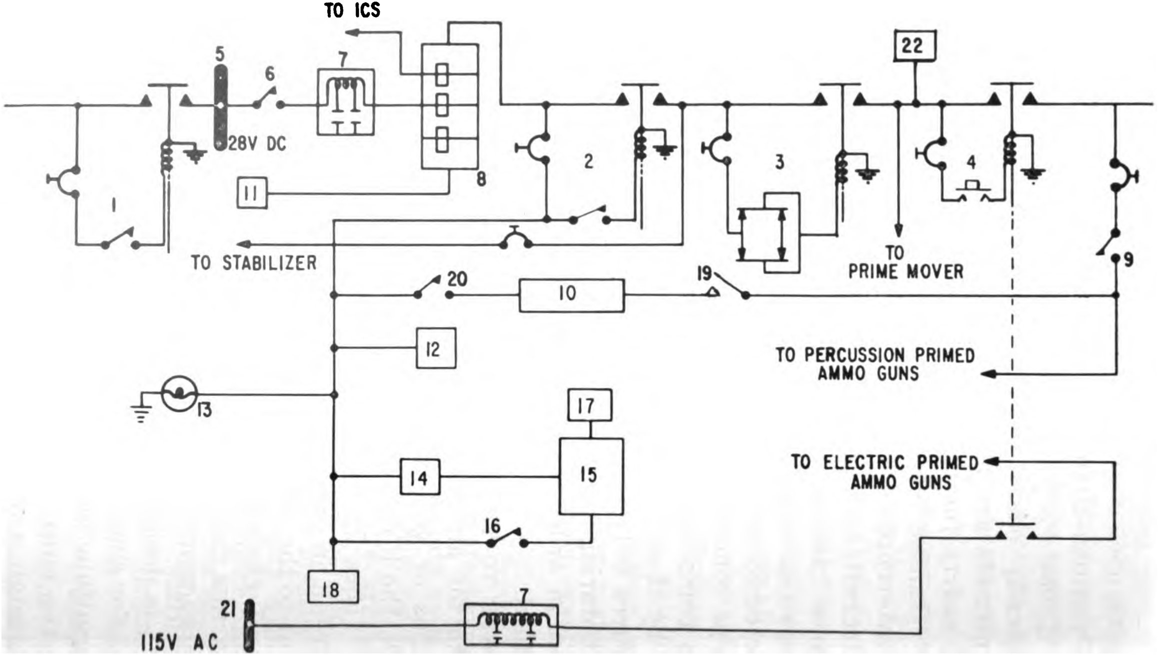


Figure 6—1.—Electric drive turret power schematic.

Nomenclature for figure 6—1

1. Battery switch and relay.
2. Master switch and relay.
3. Action relay and switch.
4. Gunfiring relay and switch.
5. Bus (28-volts, d-c).
6. Emergency switch.
7. Noise filter.
8. Power brush assembly.
9. Gun ON-OFF switch.
10. Ammunition booster.
11. Intercommunications system.
12. Suit heater receptacle.
13. Trouble light.
14. Voltage regulator.
15. Gunsight.
16. Boresight switch.
17. CG—4 camera.
18. Compressor.
19. Micro switch.
20. Booster loading switch.
21. Bus (115-volt, a-c).
22. Smoke doors.

---

from the collector ring to the turret proper. Due to this arrangement, the turret has complete freedom of azimuthal rotation. Power from the brush assembly is led to the various turret buses and turret switches for operation of relays which will further distribute it to turret components.

The bulk of the power (amperage) to the turret is distributed by the master switch and relay. The remainder of the current to the turret feeding such components as the suit heater, trouble lights, ammunition boosters, sight unit and regulator, boresight switch and compressor, is derived from a point in the power circuit AHEAD of the master switch. The SUIT HEATER outlet is situated conveniently to the turret operator. There are several methods of mounting the TROUBLE LIGHTS. Basically, they are mounted so that they may be swivelled about their mounts allowing the light to be focused where needed. The AMMUNITION BOOSTERS are wired so that they may be used to aid in loading ammunition. The PNEUMATIC COMPRESSOR also gets its power from ahead of the master switch so that it may perform its functions without energizing the many other components of the turret.

Power is furnished to the stabilization system of one series turret from the master switch and relay. The servo amplifier contains a TIME DELAY RELAY which functions to afford time for the amplifier to warm up prior to its being used in the controller circuits. A heater element in the delay device provides a preset time interval before allowing the contacts to close, thus bringing the amplifier into the circuit at its proper operating temperature. Were it not for this time delay feature, the action of the turret would be uncontrollable once the master and action switches were energized prior to warmup of the servo amplifier. The delaying action is usually about 30 seconds duration.

Current (aircraft supply) from the controller contacts during displacements of the controller handles is fed to the control generators from which current is taken to operate the turret drive motors. Likewise, the small current differential generated by precession of the azimuth and elevation gyroscopes of the STABILIZATION SYSTEM is fed to the servo amplifier and boosted. It is then further sent into the stabilization system where it is used to operate the servomotors. The servomotors operate servo potentiometers which place a voltage into the transmitter-receiver circuit which aids or opposes the voltage produced by the transmitter. In so doing, the stabilizer is able to control the movements of the turret in pitch, roll, and yaw and thereby afford the operator an effectively stabilized gun platform. It will be remembered that the stabilization system, even when installed, may or may not be used at the discretion of the operator.

When closed, the respective relays of the master and action switches furnish power to the prime mover of the motor-generator. The prime mover drives both the elevation and azimuth generators from a common shaft. (See fig. 6–2.) With the gun selector switches closed, the firing circuit becomes operative at the same time that the prime mover is energized. The gunfire switch may be depressed at this time closing the firing relay and furnishing power to the gun ON-OFF switches. Certain series turrets incorporate a gun circuit which is auxiliary and which is completely operative without closing the master switch or action switches. When the gun switches are placed on the ON position and the selector switches set to INDIVIDUAL, the right-hand trigger switch will operate the right-hand gun. The left-hand trigger switch will operate the left-hand gun. With the selector switch set to BOTH under the same circumstances, either trigger switch will operate both guns. In one series turret both guns are fired by closing the following switches in order: Master switch, gunfire switch, action switches, and trigger switches. In another series turret the profile interrupter is in the firing circuit. (Nomenclature of various aircraft electrical switches is not entirely firm, hence the names used in this course will be those found to be most descriptive of the individual item.)

In a gunnery system employing the electric primed ammunition, a separate source of power has to be provided in addition to the 28-volt current from the aircraft. It is necessary to pass 115-volt, 400-cycle a.c. through a TRANSFORMER in order to boost the current to properly fire the primer of this type ammunition. The gunfiring relay is operated by the same 28-volt d.c. as are other relays throughout the aircraft. However, the current controlled by the gunfiring relay in this instance is derived from the 115-volt bus of the aircraft, and is stepped up to between 200 and 300 volts. NOISE filters are placed in the circuit to eliminate interference. When the gunfiring relay and other switches in the circuit are closed preparatory to firing the guns, power is made available to the ammunition booster MICRO SWITCHES. The boosters will then operate as soon as called upon through their actuation by the belted ammunition tension.

The 115-volt, 400-cycle, a-c power used to fire the guns and perform other duties within the aircraft is ordinarily derived from one of two sources. One source is from a special GENERATOR(S), the other from an INVERTER. The generator(s) is normally engine driven, and may vary in number from one to several depending on the aircraft involved. The inverter, however, takes the aircraft supplied 28-volt, d-c power and alters it to

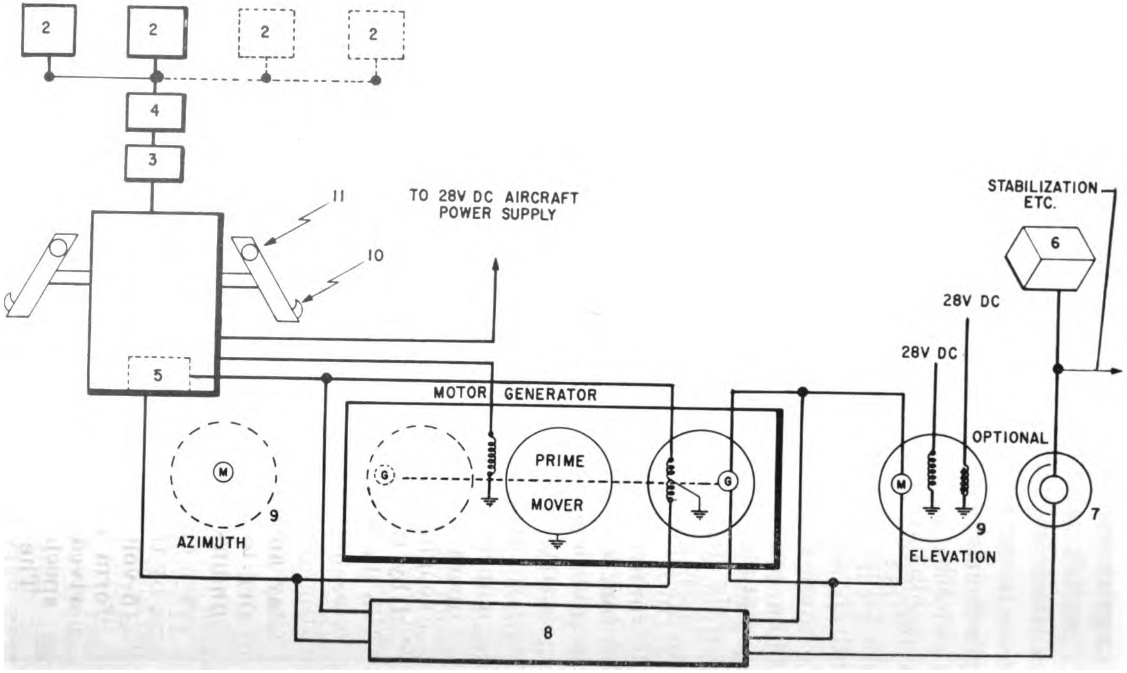


Figure 6—2.—Turret control and drive schematic.

Nomenclature for figure 6–2

1. Controller.
2. Gun solenoids.
3. Indicator light.
4. Gunfire interrupter.
5. Receiver.
6. Structural interrupter.
7. Transmitter (elevation).
8. Main junction box.
9. Turret drive motors.
10. Action switches.
11. Trigger switches.

115-volt, 400-cycle a.c. which is then led through a transformer as before to rectify and step up the voltage to the proper working level for the guns. The noise filter mentioned previously prevents unwanted interference from entering the intercommunications receivers of the aircraft. These filters are used in both the a-c as well as the d-c circuits.

The gunsight may or may not be associated with the aircraft fire control system for target tracking. In either event, the gunsight is supplied with power from a VOLTAGE REGULATOR in order that the current at the gunsight will always be at a constant value. Illumination of the reticle should not vary while the sight is in use. In some of the gunsights, the gyroscopes have to be fed by a constant current so that there will be no fluctuations in the spin rate to cause variations in precession. Both the gunsight and the fire control system draw their power from a point aft (downstream) the master switch and relay. A check of figure 6–1 shows how the BORESIGHT SWITCH is wired for operation. It will be noted that the boresight switch may be employed without energizing other components of the turret. In other words, the boresight switch may be used without turning on any other components of the turret by closing the aircraft's battery switch.

The GUNSIGHT RECORDING CAMERA (CG–4) is connected to the gunfiring relay or the foot ranging pedal so that when the gun triggers are depressed to fire the guns, power is available to the camera from the relay. BEFORE CONNECTING THE CAMERA, CHECK FOR PROPER POLARITY. If incorrectly connected, the camera will run backwards.

The INTERCOMMUNICATIONS SYSTEM (ICS) of the aircraft extends into the turret as well as other parts of the aircraft. Inside the turret there is an interphone box with all the necessary controls to enable the operator to make full use of the system throughout the aircraft. The box is fitted with headphone and microphone connections for use by the operator.

A SUIT HEATER outlet is provided for connection of the turret operator's heated suit to the electrical system of of the aircraft. Power to energize this suit is derived from the battery bus so that the operator may be comfortably warm without the necessity of energizing the master switch and relay which affects most of the other turret components.

The SMOKE DOORS of one series turret are connected into the gunfiring circuit. They operate when the master switch and the FIRE-SAFE switch are closed.

AMMUNITION BOOSTER MOTORS may be energized by two separated switches—the micro switch and the booster loading switch. The micro switch actuates when the tension from the belted ammunition is sufficient to close its contacts, thus starting the booster motors. The booster loading switch is manually operated to start the booster as an aid in loading ammunition into the guns. All booster motors automatically shut off if the guns jam.

The MOTOR-GENERATOR assembly includes three distinct armatures mounted on one shaft. The center armature with its associated fields comprises the prime mover. The prime mover is a constant speed electric motor energized by the aircraft's power supply when the appropriate switches are closed. The other two armatures along with their respective fields are the azimuth and elevation generators. These generators produce no voltage while running without their field loads. Three fields are provided to control these generators of the motor-generator unit. One is a shunt-wound field which assures a constant output of the generator, and the other two fields control the direction of the current flow (positive to negative and vice versa), thereby determining the direction of rotation of the drive motors. The prime mover is a 2¼-horsepower compound wound assembly and the generators are separately excited, split-field, shunt-wound units. The combined output of the two generators is approximately 1,400 watts, but either one of these generators will deliver a maximum of 1,000 watts alone. In another series turret the prime mover is rated at 6 horsepower, and the combined output of the generators is 6,000 watts. Power to drive the prime mover of the motor-generator is derived from the master switch and relay. The action switches of the turret controller are employed to control this supply to the prime mover.

The TURRET DRIVE MOTORS are reversible d-c units rated at one horsepower for intermittent duty. A worm gear on one end of their shafts drives the turret through an integral gearbox arrangement. The other ends of their shafts have spur gears fitted to drive the transmitters. The drive motors of one series turret are equipped with electric brakes which stop the rotation of the motors quickly once the current is shut off.

The TRANSMITTERS are mounted to the commutator ends of the drive motors by an adapter and geared in a one-to-one ratio with the drive motors. The transmitters are permanent magnet linear-response generators; that is, for each increase in r.p.m., there is a proportional increase in voltage. These transmitters are rated at about 48 volts d.c. at 6,000 r.p.m. with a 0.6-ampere load.

The AZIMUTH AND ELEVATION RECEIVERS are contained in the controller unit and are mechanically connected to the hand controller grips. They are identical units and basically transmit mechanically the torque generated by the hand controller grips; complete a circuit through the generator of the motor-generator unit; cycle the opening and closing of the contacts (fixed and movable); and produce higher rates of velocity at the turret drive motors during changes in controller grip displacements. The receiver units contain a torque motor, a drag cup assembly, and electrical contacts and gearing. The torque motor armature supports a movable contact arm at one end and the drag cup at the other. Movements of the controller grips cause the torsion spring to close the movable contacts against the fixed contacts. The control generator field is thus excited, causing the generator to have an output. The drive motors are then energized and start running, thereby driving the transmitters. The transmitters produce a voltage directly proportional to the speed of the drive motors. The voltage from the transmitters is connected across the receiver torque motors, causing these motors to open the contacts when the voltage from the transmitters is high enough. Opening of these contacts drops the generator output to zero, slows the drive motors, drops the transmitter output, and causes the torsion spring to overcome the torque motor. The contacts are then able to close again, and the cycling recommences.

During displacements of the controller grips, the drag cups aid in tracking only. Rapid displacements of the controller grips from zero to maximum are aided by the drag cups as they help the torsion spring hold the contacts closed so that the turret will build up speed proportional to the controller grip displacements. During small displacements, the drag cups oppose the torsion springs holding the contacts open, so as to slow down the turret proportionally to the controller grip displacements.

The turret controller circuits and mechanisms are used to produce a signal which controls the rate of movement of the turret. The CONTROLLER also provides a base for conveniently located switches for energizing the drive circuits, firing the turret guns, arming the bomb release circuit, and energizing the operator's microphone circuits. In some installations, there is a controller junction box associated with the controller. This arrangement makes it extremely convenient for the operator to energize other auxiliary components of the turret without too much diversion of his attention from tracking the target. Each manufacturer will possibly incorporate some variations with regard to arrangement of the switches on the controller and the controller junction box, as well as other physical differences of the units themselves. The major components of the controller assembly are the action switches, the azimuth control, the elevation control, the trigger switches, and the microphone switches. The action switches act as safety devices in that the turret will not operate unless one of these two switches is closed. Closing one or both these switches allows current to flow to the motor-generator for its operation, and to other previously warmed-up elements of the turret.

The azimuth and elevation controls are very much alike; the only difference being a variation in the drive linkage from the control handles. When the azimuth and elevation transmitters and receivers are used in the turret control circuit, a stabilizing feedback transformer is incorporated which boosts the voltage strength generated by the azimuth and elevation transmitters to the proper working voltage. This boosting is performed to smooth out the operation of the turret by increasing the cycling operation of the generator control circuit. If the system also incorporates a stabilization system, voltage signals from the servo potentiometers equal to the undesired movement of the aircraft are algebraically added to the transmitter-receiver circuit. This signal is applied to the receivers in the controller and will energize the turret drive motors in such a manner as to keep the guns pointing in the proper direction.

The **TRIGGER SWITCHES** are located on each of the twin handgrips of the controller. They are wired in one series turret so that both guns may be fired after closing either of the switches. Control over the selective action in this case is afforded by the gun selector switches. Also, in the turrets provided with electric primed ammunition guns, there is a FREE-SYNCH switch which allows the operator to select the type of fire desired—either free fire or synchronized fire. The microphone switches are built into the twin grips of the controller. Depressing either of these two switches connects the turret operator's microphone to the intercommunication system of the aircraft.

The STRUCTURAL INTERRUPTER functions to insure that the turret and guns will stay at all times within the limits of elevation at any and all arcs of rotation in azimuth regardless of how the controller handles are manipulated. The interrupter essentially consists of one or more torque motors and a series of cams, contacts, arms, and gears. There are many types of interrupter circuits as well as a variety of interrupters in service today. Nevertheless, they are all used to interrupt the elevation and azimuth drive circuits, and exert control over the contour travel. They all incorporate cams that are driven by movements of the turret and guns, and have associated as integral parts such micro switches as are necessary to limit, interrupt, or alter, the actions of the turret for the safety of the aircraft and personnel involved.

The circuits of the interrupter are energized by displacements of its contact arms from neutral. In some types the contact arms are connected to the shafts of the torque motors, and in others they are connected to the fields of the motors. They contact the cams which are spring loaded to return to neutral when not being displaced by the cams. When the cams displace the contact arms, closing the circuits, a counter voltage is generated within the control circuit which either slows down or stops the turret drive motors depending on the velocity with which the turret approaches its limits of azimuth and elevation. This counter voltage is generated by displacement of the rotors (armatures) of the torque motors about their motor fields. The displacement of the rotors is brought about by mechanical linkage (flexible shafting) from the turret drive sector gearing.

The GUNFIRE INTERRUPTER is at times built integral with the structural interrupter and at other times as a separate unit. In either event, its function is to cut off power to fire the guns during specified intervals and arcs of azimuth and elevation travel of the turret and guns. The heart of the gunfire interrupter is the set of actuating cams which control the firing of the guns. Each type and model of aircraft as well as each turret location about the particular aircraft requires its own special cam. Each interrupter has one or more micro switches wired in series with the gun trigger switches. When these micro switches ride on the accurately formed and positioned cams, the circuit from the trigger switches to the gunfiring relay is opened. During the time that the micro switches are riding on the cams, the guns will not fire because the solenoids of the 28-volt gun system and the 115-volt gun system do not receive power from the gunfiring relay.

INDICATOR LIGHTS are installed in the turret to tell the operator just exactly when what components of the turret are operating. Such indicator lights may be wired to the searchlight circuits, the radar, the guns, and other components depending on the need. These lights will show the condition of the components as to their readiness.

The turret MAIN JUNCTION BOX contains all the wiring for the various turret components. Distribution from a centrally located junction box affords an uncluttered turret interior and eases maintenance and troubleshooting problems.

Figure 6–3 box diagrams indicate many of the auxiliary components used in aircraft and turret. A number of these components have been developed and utilized due to the increasing necessity of more rapidly solving the fire control problems associated with the ever-increasing speeds of our aircraft. The STABILIZATION

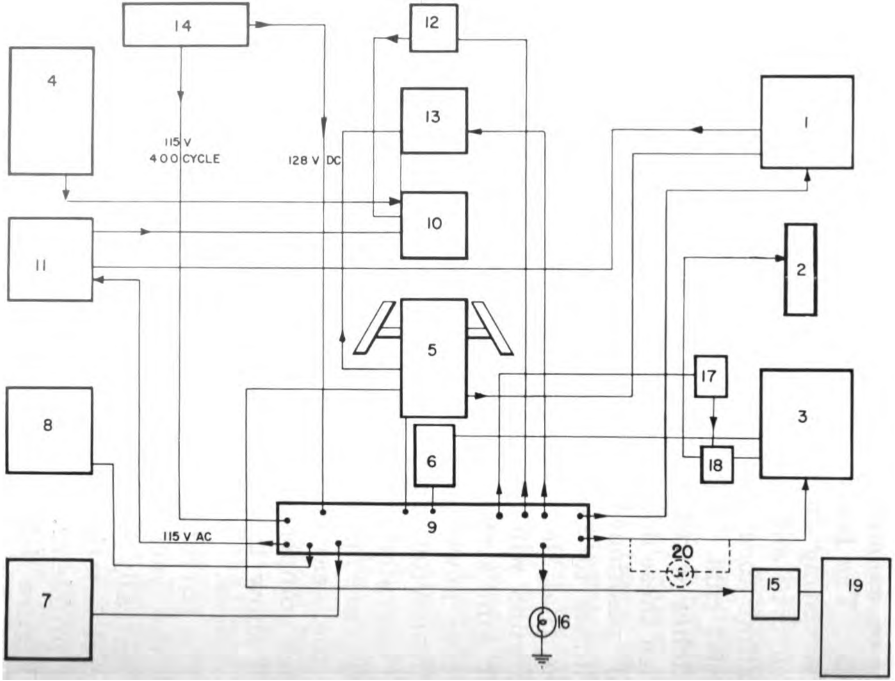


Figure 6—3.—Auxiliary components.

Nomenclature for figure 6—3

1. Stabilizer.
2. Electric primed ammuntion guns.
3. Searchlight.
4. Radar.
5. Controller.
6. Searchlight foot switch.
7. Gun camera.
8. Pneumatic compressor.
9. Control junction box.
10. Gunsight.
11. AFCS.
12. Voltage regulator.
13. CG—4 camera.
14. Power entry box.
15. Time delay relay.
16. Trouble light.
17. Inverter.
18. Transformer.
19. Motor-generator.
20. Searchlight overheat indicator.

SYSTEM may at first glance be thought of as an auxiliary component for the convenience of the turret operator in keeping his turret steady. However, this component has to a large measure been responsible for increased efficiency in gunnery, bombing, and ASW scores and combat hits. It is connected to a remotely controlled searchlight for ASW work. The turret operator, in being able to work from a highly stable platform while tracking, firing, bombing, and other work, is immensely aided in carrying out his duties. Rough air and aircraft maneuvers are smoothed out by the stabilization gear much more effectively than possible by manual control. This gear will be discussed later in the chapter.

The turret operator may fire the guns, and make searchlight runs at will by using only the fire control system sight of the turret. By use of a special switch, the navigator may turn over control of the searchlight to the turret operator. Radar is becoming an increasingly more important part of the aircraft turret. Its capabilities so far outdistance those of the human being in many functions that its use is becoming practically mandatory. Radar's ability to lock on to preselected targets, furnish all the factors for the fire control problem, and to operate successfully in all types of weather, make it practically indispensable.

The switches on the turret controller are used to energize some of the turret components mentioned above. However, there are numerous controls for the turret which cannot be located on the centrally situated controller. As a rule, these are located on the CONTROL JUNCTION BOX. Being located on this junction box, they are still within easy reach of the operator.

The SEARCHLIGHT is controlled remotely by hydraulics and power is fed to it by a foot switch. There is an indicator light to show who has control of the searchlight—the navigator or the turret operator. There is also an overheat indicator light which becomes illuminated if and when the searchlight assembly becomes too hot for operation. A special circuit outside the turret contains a step-up transformer to produce the heavy current necessary to operate the searchlight's carbon arcs.

The 28-volt d-c and the 115-volt a-c power to the aircraft turret is led from the POWER ENTRY BOX (which is sometimes the main junction box) to the control junction box as shown in figure 6–3. It must be understood that the routing of power to and within the turret in this figure is only one of many methods that can and have been employed. Practically every manufacturer of aircraft turrets employes a differing technique of power distribution. The method indicated in figure 6–3 is fairly representative. From the control junction box the power is distributed throughout the turret to the various components. This distribution is made through relays, resistors, circuit breakers, etc. There may be numerous auxiliary junction boxes within the turret, and each of these is energized in turn from the control or main junction box. Such items as the TROUBLE LIGHTS take their power from one of the earliest boxes in the line in order to minimize their chances of failure. Troubles within the later boxes may then be traced with the aid of these lights whose power is still flowing from its source.

The gunsight derives its power from two sources. One circuit comes directly from the power entry box and feeds the boresight switch of the gunsight. The other comes from the power entry box through the normal urret circuitry to the gunsight. At some point in this tter circuit, power is led through a voltage regulator hich functions to maintain the lamp of the sight at a onstant brilliancy.

In turrets containing AIRCRAFT FIRE CONTROL SYSTEMS, is necessary to allow a warmup period of specified uration. A TIME DELAY RELAY used for this purpose powered during the warmup period by current from e master switch and relay. The basic function of the ime delay relay is to prevent the turret from operating ntil certain elements of the stabilization gear and other urret controls have had time to warm up sufficiently or proper operation. As soon as these elements have ome up to their correct operating temperatures, a ther-al switch within the time delay relay closes the circuits ecessary for operation of the turret. When the warm-p has been completed, the control amplifier is ready to xert its influence on the turret drive motors. As the ontroller is now displaced from its neutral position, the rive motors will operate. In effect, the time delay relay ctually opens the circuit to the control fields of the otor-generator prime mover and keeps this circuit pen until the amplifier has had time to reach operating emperature.

The GUNSIGHT RECORDING CAMERA (CG–4) is situated n the gunsight of the turret and is connected to the M3 gun control box from which it received its control urrent. During the time in which the turret operator s tracking a target and during actual firing of the guns, he CG–4 camera is operating at a speed of 3 frames er second. A solenoid operated witness marker shows in each frame while the operator is tracking, but on depressing the trigger switches, the solenoid actuates withdrawing the witness marker from the picture frame. This camera contains its own noise suppressor.

The PNEUMATIC COMPRESSOR is driven by power from the main junction box. This component furnishes the motivating power for the gun chargers and/or feed mechanisms.

Current from the INVERTER is led through a transformer which steps up the current for use in firing electric primed ammunition guns. Current flow commences when the trigger switches are depressed and the transformer output is routed through the gunfiring relay to the firing pin of the guns where it fires the ammunition.

Figure 6–4 shows the relays and switches in the various circuits employed for firing the two types of ammunition currently used in the 20-mm aircraft guns—the electric primed ammunition and the percussion primed ammunition. The MASTER RELAY is closed by the turret operator in preparation for using the turret. Power from the master switch is led to the ACTION SWITCHES AND RELAYS, and from there to the FIRE-SAFE SWITCH. From this switch the power is routed through the GUN CHARGING FIRING CONTROL RELAY and SWITCH which is controlled and actuated by the pressure (pneumatic) which operates the gun chargers. The pressure switch does not operate the gun charger release relay until the proper cycle of the chargers has taken place. The circuits and the nomenclature of elements shown in figure 6–4 are not necessarily those shown in other schematics, but, here again, the figure is fairly representative and the nomenclature of the various electrical features are those found to be the most descriptive of the individual item.

The GUN CAMERA and the BOOSTER SYSTEMS become operative when the trigger and certain other switches are closed in the installations using both percussion and electric primed ammunition. The percussion primed ammunition is fired by the firing pin striking the primer of the rounds. The bolt of the gun using percussion primed ammunition is held and released by a solenoid. This solenoid receives its power from the gunfiring relay. Gun selector switches in the circuit permit firing either gun or both guns simultaneously in electric primed ammunition gun installations. In some installations, the ıns have PUSH-PULL resets between the relay and ıe gun solenoids. In others, the circuit is further con-·olled by a READY-OFF-SAFE switch (the FIRE-AFE switch in fig. 6–4), which is used to open the gun rcuits in the event that the guns are not properly ıarged. The electric primed ammunition guns require vo separate voltages in order to fire. The 28-volt, d-c ɔltage is used to actuate the relays which feed 115-volt, ·c power to a transformer. This transformer steps up ıe current to 200-300 volts for use in firing the electric rimed ammunition. The 115 volts are fed to the rimary of the transformer, and the resulting output rom the secondary is converted to direct current by ectifiers in the bridge circuit of the transformer.

The rectified and stepped-up current from the trans-ɔrmer is led to the gunfiring controls of the electric rimed ammunition gun system. The firing controls, roperly energized by the current from the turret's 28-olt bus, will pass the rectified current through to the uns by way of the FREE-SYNCH switches. The re-istors of the gunfiring controls act as a safety feature ı that an electrical short in the line to one gun is ab-orbed to ground by this resistor thereby allowing the ther gun to continue to operate. The gunfiring control ircuit also receives overall protection by incorporating ircuit breakers. The condensers in these controls serve o protect the contacts of the switch and to reduce the nake-and-break noises in the line.

The gun camera may be wired in one of several dif-erent manners. However, the usual method is to place t into the circuit so that it will become operative as the gunfiring relay is energized by closing of the trigger switches. The gun camera may also be operated by closing the GUN CAMERA TEST SWITCH. In order to keep moisture from condensing on the optical system of the camera and to keep the lubricant in the working parts of the camera from congealing, a GUN CAMERA HEATER is installed within the camera. This heater is wired so

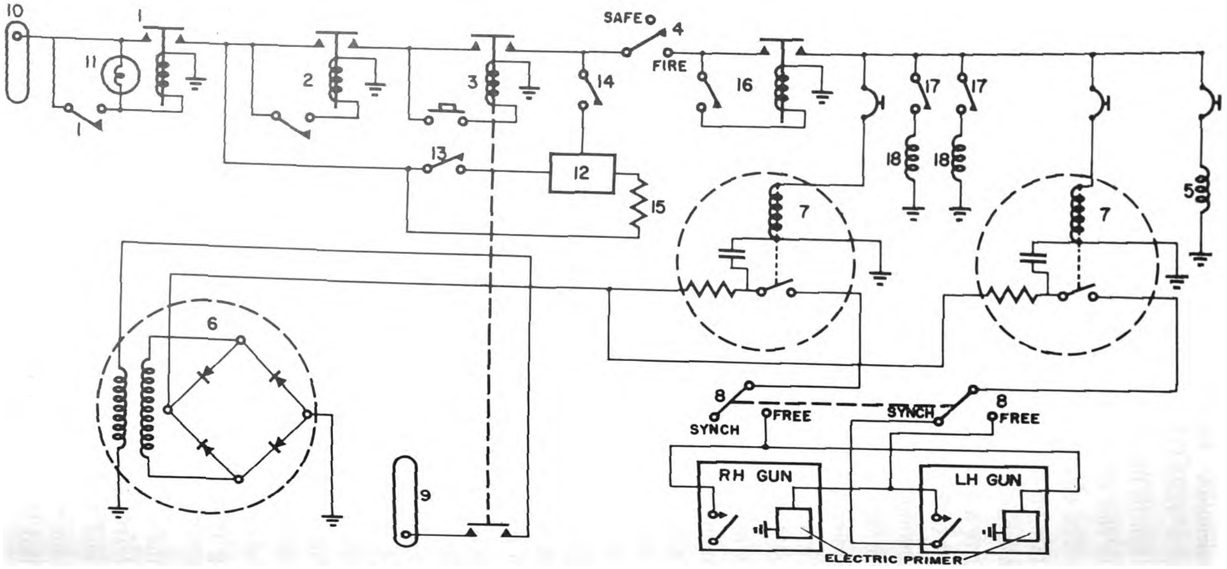


Figure 6—4.—Control and firing circuits for electric primed and percussion primed ammunition guns.

Nomenclature for figure 6—4

. Master relay and switch.
2. Action relay and switch.
3. Trigger switch and gunfiring relay.
4. FIRE-SAFE switch.
5. Booster relay.
6. Transformer.
7. Gunfiring controls.
8. FREE-SYNCH switch.
9. 115-volt bus.
10. 28-volt bus.
11. Indicator light.
12. Gun camera.
13. Gun camera test switch.
14. Gun camera switch.
15. Camera heater.
16. Gun charging firing control relay.
17. Gun selector switch.
18. Gunfiring solenoids (percussion primed ammunition guns).

hat it is energized during the entire time that the bat-ery switch is in the ON position.

COMPONENTS OF THE AZIMUTH AND ELEVATION DRIVES. —Probably the most important components of the elec-ric drive turret are the azimuth and elevation drives hrough which the guns are brought to bear on the arget with speed and smoothness. The smooth and apid movements of the turret are produced by a motor-enerator drive system. The motor-generator unit fur-ishes power to drive both the azimuth and elevation lrive motors through their separately excited fields in he exact amounts and at the exact rates called for by lisplacements of the controller handles. This power may e varied from zero to 27.5 volts, providing movements f the turret from a "crawling" speed of only a few de-rees of arc per second to very rapid motion in both ver-ical and horizontal planes when the controller handles re displaced hard over in azimuth or depressed and ele-ated rapidly.

Displacements of the controller handles from their normal (zero) position in either azimuth or elevation produces an output of the motor-generator by energizing the appropriate fields of the generator. The output of the generator is varied by the cycling operation of the receiver contacts. The longer the contacts are closed the greater is the output, and vice versa. The resulting output from the motor-generator is led to the azimuth and elevation drive motors whose speed and direction of rotation are controlled by the amount and direction of current flow received from the generator. The drive motors only operate upon receipt of this current from the generator and release of their brakes electrically.

The azimuth and elevation drive motors are identical in construction. However, the gearbox, the clutch, and the housing for these components are likely to vary widely with the manufacturer and the installation involved. The gearbox contains a gear train which affords the proper reduction ratio for the needs of the turret involved. A clutch which may be manually operated is provided within the gearbox to disengage the drive motor and allow the manual crank to operate the turret. Both the azimuth and elevation drive motor assemblies are so provided in order that the turret may be rotated and elevated or depressed. The azimuth drive gear mates with a ring gear which is fastened to the turret and rotates the turret in either direction depending on the displacement of the controller in azimuth. The elevation drive gear meshes with a vertically positioned gear sector which is connected with either the turret ball or the gun trunnions depending on the type of turret. In the ball-type turret, the ball will move as a unit in elevation or depression thus necessitating that the drive gear sector be secured to the ring assembly. However, in other installations the turret does not move in elevation or depression, just the guns. In this installation, the drive gear sector is secured to the gun trunnions for movement in the vertical plane.

MANUAL TURRET OPERATION.—The manual cranks for both azimuth and elevation movements of the turret are normally disengaged and swung out of the way. They are put into use by moving them from their stowed positions and engaging them with their respective drive shafts to the azimuth and elevation drive motor gearboxes. Other installations are so designed that there are separate controls to disengage the clutches through flexible cables. In this type, the manual drive handles are engaged and the clutch then disengaged through operation of a separate lever. The manual drives are used mainly as a means of returning the turret to its normal or zero position in the case of power failure so that the operator may emerge from the turret. Other uses of the manual drives include boresighting, testing movements of the turret, positioning of the turret for cleaning and caring for the guns.

GUNS AND GUN FEED MECHANISMS.—The first machine-guns fired successfully from our naval aircraft were .30 caliber guns. Some time later the .50 caliber guns replaced the .30's. World War II saw the height of our conversion to the 20-mm guns for aircraft use. Their rapid development has overshadowed that of any other type gun for aircraft use. Different types of guns will be developed in the near future, but our immediate concern is with the 20-mm guns. A great variety of explosive ammunition has been developed for the 20-mm gun. Each type has its own specialized use in modern tactics. This ammunition is made in tracer, ball, incendiary, high explosive, armor piercing, and combined forms of these types. The Navy currently uses less than half a dozen types of 20-mm guns, both in its turrets and in the fixed gun installations.

Feed mechanisms are required to move the heavy belted ammunition to the guns. These mechanisms have been improved and modified to keep pace with improvements in the guns. Pneumatic pressure and mechanical spring energy stored up by moving parts of the gun are used in different types of feed mechanisms as a source of power for their operation. In a number of installations, the belted ammunition has to travel some distance before it reaches the guns. This fact requires that the feed mechanisms be sturdy and powerful. In spite of this fact there are instances in which ammunition boosters have to be employed to aid in getting the gun ammunition to the feed mechanisms.

Original naval aircraft turrets contained the .50 caliber machine guns. As time went on, these turrets were improved in rapidity of movement and smoothness of operation, the rate of fire stepped up, and many other physical changes were made for the overall improvement of the turret. However, a clearly defined need arose for guns of greater firepower and range. As a result, the 20-mm guns were placed in the turrets. These guns performed most satisfactorily. It was necessary, however, to strengthen the turret frames, makes the drives more powerful, and redesign the turret in other respects to offset the effects of these much heavier and more powerful guns.

In certain installations, the ammunition cans are situated at some distance from the guns and the feed mechanisms were unable to pull the belted ammunition over such long distances. As a result, ammunition boosters were added at proper locations along the ammunition chuting to insure that the feed mechanisms were relieved of most of the strain and that the ammunition was delivered to the guns properly. Since the guns were increased in size and power, the gun mounts likewise had to be improved and strengthened. These devices are subject to great shock from recoil and counterrecoil as well as accelerations of gravity in maneuvers. Their locks have to be positive and the entire assembly strong beyond normal expectations to function with safety over long periods.

The various 20-mm guns used by the Navy in aircraft differ in their internal makeup, the manner in which they are fed ammunition, the manner in which they are charged, their rate of fire, and other aspects. One gun has a charging device which is cast integrally with the gun receiver; others have chargers which are secured to their receivers through a latch and bracket assembly. One gun has no drive spring to return the bolt to battery, and employs counterrecoil from a pneumatic buffer to perform this action; others incorporate a drive spring to absorb the shock of recoil and aid in returning the bolt to battery. One gun has a pneumatic feed mechanism to supply ammunition to the gun; others derive their power to feed ammunition through mechanical spring action of the feed mechanism. The rate of fire of the different 20-mm guns, while fairly close to the same figure, is faster in some guns than in others due to certain design features.

The feed mechanisms of the 20-mm guns are currently of several basic designs. One of these designs is a pneumatic feed system which employs a low-profile mechanism operated by pneumatic pressure from its own pressure source. Pneumatic pressure operates a reciprocating piston to shuttle the ammunition into the throat of the gun after having stripped off the links. It is a very effective and fast operating device. Another type employs energy from a spring to feed the ammunition. This spring is constantly being wound by cam action from the reciprocating parts of the gun during firing. While its bulk and greater height above the gun is greater than the pneumatic type, it is still an effective and dependable mechanism. There are other types of feed mechanisms which have been recently developed and tested. However, it still remains to be seen how they will stand up under operational use with the squadrons of the fleet.

Ammunition boosters, previously mentioned, are necessary in many gun installations as an aid in getting the ammunition to the guns. They are invariably driven by electric motors. They are self-contained units dependent on the aircraft only for power with which to operate. Actuation of the booster is accomplished through a spring-loaded micro switch. As the feed mechanism of the gun puts a strain on the belted ammunition during operation of the gun, the spring-loaded switch on the booster closes, starting the booster motor when the proper firing control switches are closed. As the ammunition is drawn from the can by the booster and is forced towards the feed mechanism through the ammunition chuting in a quantity more than sufficient to supply the gun, the strain on the spring in the micro switch is relieved sufficiently to again open the switch stopping the booster motor. The aircraft gun will actually fire successfully in most cases without the aid of the booster However, the booster renders aid in getting the ammunition to the gun, thereby allowing the gun to fire at it maximum rate without being slowed down by havin to pull the heavy belted ammunition from the can b itself.

Aircraft gun mounts are manufactured in many designs in order that they may be adapted to the particula installation in which employed with maximum effectiveness. Basically, the gun mounts all form a substanti and secure means of attachment of the guns to th aircraft. They are all designed so that the guns the support may be quickly detached for cleaning, replacement, and maintenance. The design also incorporate an adequate locking device that assures that the gun wil not become loose while firing or become damaged due to other forms of vibration and shock.

Ammunition cans are normally located as near the guns they feed as possible in order to reduce the amount of necessary chuting to the minimum and to reduce the energy necessary to pull the ammunition to the guns. There are many different manners of laying out ammunition chuting. In each installation the designer attempts to get the cans as close to the guns as possible, the chuting installed in smooth uninterrupted curves throughout its length, and the boosters installed at the precise locations along the chuting where they will be the most effective.

BORESIGHTING of the guns of the aircraft turret is normally accomplished by the parallel method. That is, the guns are boresighted so that their lines of fire are parallel for all actual firing purposes out to infinity. The current practice is to use prepared boresight screens for the particular aircraft involved with which to perform the actual boresighting. These screens are erected at specified distances from the aircraft turret being boresighted, both ashore and aboard ship. The further the boresight screen is from the aircraft being boresighted.

he more accurately the boresighting job may be performed, other factors being equal. Some screens are marked with definite specifications as to how far (to the nch) they must be erected in front of the turret guns being boresighted.

Parallel boresighting is most accurately accomplished ashore, and accomplished there most accurately by using a distant object upon which to boresight the guns instead of a boresight screen at some prescribed short distance ahead of the guns. Performing the boresighting on any clearly defined object one mile from the aircraft, gives excellent results. Minute error inadvertenty made during the boresighting process will cause much smaller errors in the final boresight results using this system than in using the closely placed screen system.

SAFETY DEVICES AND SAFETY CONTROLS.—The aircraft turret has many safety devices and controls. Some of these may not seem to be actual safety devices for the protection of the turret, aircraft, and personnel. However, after some reflection it may be seen that they do just that. For example, gun chargers do not necessarily bring to mind a meaning of safety in the operation of the turret. However, prompt use of the gun charger may easily save the lives of personnel and avert damage to property in the event of a "runaway" gun. Thus, the gun charger is definitely a safety device in this sense.

All electric turrets have an EMERGENCY SWITCH located on the outside of the turret. This switch is situated so that it is readily accessible to crew members outside the turret. It may be opened at any time a malfunction occurs, damage is sustained by the turret, or the operator is injured. In effect, this switch cuts off all power to the turret, deenergizing all components of the turret as well as the turret drives.

CONDENSERS (capacitors) often act as safety devices in suppression of arcing and sparks caused by loose connections, arcing contacts, brushes arcing, and from other sources. They are also employed to reduce or eliminate interference in radio receivers. Arcing has caused explosions of vapors trapped within the aircraft and interference in receivers has caused important messages to go unheeded. Thus, it is that condensers may be classed as safety devices.

The MASTER RELAY CIRCUIT BREAKER SWITCH acts as a safety device in any and all turret components which derive power through the master switch. Practically all of the turret components have their own circui breakers, but as an added precaution the master switc is also protected as stated.

The TIME DELAY RELAY is considered a safety devic in that it will not allow the turret to become operativ prior to the time that all the components are capabl of correctly controlling the turret. Otherwise, the turret may damage itself and injure personnel because o erratic movements were it allowed to operate before a components were ready to function properly.

The master switch safety circuit and the other circui breakers of the electric aircraft turret are tripped o actuated THERMALLY. This is to say, heat is made t open or close this switch and these breakers. Bimetalli strips are used to actuate the switch or breaker. Hea generated from overloads in the circuit and from direc shorts is made to open or close contacts depending o the type of unit concerned. In the time delay relay, th heater causes enclosed bimetallic elements to close a se of contacts within a specified time lapse. In othe units such as circuit breakers, the FIRE-SAFE switch the ON-OFF switch, the READY-OFF-SAFE switch and others, the thermal unit causes the circuits to b deenergized as soon as sufficient heat generated withi the circuit moves the bimetallic elements to any extent It is seen that each of these units is a safety devic within itself, and in some cases a safety control as well

For direct operator protection and safety in the turre there are ARMOR PLATING and BULLET-RESISTANT GLASS These units are placed within the turret at locations known to offer the ultimate in protection for the particular installation involved.

One series of turrets has MANUAL CONTROLS outside of ie turret proper. These controls are not as complete ; the manual controls inside of the turret. However, iey may be used successfully to make certain move-ients of the turret for testing purposes without entering ie turret, and may be used in emergencies to bring the irret back to its azimuth and elevation zeros in the ·ent that the operator is injured and unable to operate ie controls.

SMOKE DOORS are usually fitted to the turret to :avenge the smoke and gases of combustion during fir-ig of the guns. This enables the operator to work in nontoxic environment free from visibility reducing noke. Control over these doors is offered by the gun-ring controls. These doors remain open for a pre-etermined length of time after the guns have stopped ring in order to properly scavenge the fouled air with-ı the turret.

LIMITING DEVICES engineered into the turret stop the otational and elevation movements of the turret, prevent ie guns from firing at such times as would damage cer-iin structural members of the turret and aircraft, and revent possible injury to personnel. The gunfire in-errupter stops the guns during the time that their bore xes necessarily have to pass "through" parts of the ircraft. The upper and lower limit switches maintain ie guns within certain bounds of elevation and de-ression throughout the total azimuthal rotation of the irret. In certain turret installations, there are physical mit stops beyond which the turret may not move in zimuth and elevation. These are usually installed only s double safety features as the electrical stops and miting devices inherent to the turret normally perform ie function of limiting the turret to safe bounds.

GUN CHARGERS may be classed as safety devices in iat they may be used to stop "runaway" guns. By uickly activating the gun charger of the gun concerned, ie bolt is retracted and held in the aft position, thus topping the gunfire.

Certain turrets have turret drive motors which are equipped with ELECTRICALLY OPERATED SOLENOID BRAKES. As soon as the power received by the drive motor is interrupted, the brakes are automatically applied, stopping the overrun of the drive motor in the direction it happens to be rotating. This action prevents the turret from "coasting" to a stop.

All inhabited turrets (those requiring an operator within the turret proper) have a set of MANUAL TURRET CONTROLS near the operator's position. These controls are normally disengaged and stowed so that they do not interfere with electrical operation of the turret. They may be engaged at any time in order to move the turret in both azimuth and elevation for purposes of testing certain actions of the turret, or employed in an emergency to track a target after power failure to the turret. These controls may be classed as safety devices for the above reasons.

Some turrets have what may be described as EMERGENCY BYPASS features. In the main, these features consist of switches which may be activated to bypass certain safety devices in emergencies. Such a feature is the switch which bypasses a circuit breaker. Should this circuit breaker fail during combat at a time when your aircraft is being fired upon, a special switch may be closed which reenergizes the safety circuit quickly without the necessity of attempting to locate the trouble. This special emergency bypass switch, of course, should not be used unless the situation is extremely grave because it automatically deprives the turret of the safety features carefully incorporated.

Turret operators require BREATHING OXYGEN to sustain life at present day operating altitudes. The oxygen supply and the supply controls and the face mask are all part of the safety equipment of the turret.

INDICATOR LIGHTS and TROUBLE LIGHTS within the turret are considered safety devices. The indicator lights may be wired to show the condition of the guns and other vital conditions. The trouble lights are invaluable aids to the operator in locating difficulties within the turret during times of inadequate light, especially at night.

OPERATIONAL CHECKS.—In order for the aircraft turret operator (aircrewman) to successfully complete a mission in the air, be it firing runs, gun camera runs, or low level bombing, he must be completely familiar with the operating controls of the turret he is to use. This knowledge is obtained from formal schooling and practical experience. It is also necessary for the aviation personnel who service and maintain the turret to become proficient in performing an operational check of the turret. Assurance must be had that the turret will operate correctly in all respects before the person or persons conducting the check may conscientiously give the turret an "UP" for flight.

Essentially, the operational check consists of operating the various components of the turret on the ground to insure that they function as they should, and inspecting other features of the turret for security, condition, lubrication, etc. Before entering the turret, the person conducting the operational check should inspect those components associated with the turret, but which are located outside of the turret nearby. These may be some elements of the stabilization gear, turret emergency switch, turret emergency controls (manual), and others like the ammunition cans.

After completing this portion of the operational check, move carefully into the turret. If a thorough inspection of the various components and control switches indicate everything is in order, adjust the safety belt to a comfortable position and communicate with other stations within the aircraft over the intercommunications system. Do not wait until the last minute to check the turret. Start as long before the flight as possible. Some difficulties may be located and remedied before the flight. Insure that the turret and guns are trained to their azimuth and elevation zeros, then turn on the master switch. If the aircraft battery switch is ON, or an APU is operating, power is now available to most of the components of the turret. Do not operate the turret drive unless the aircraft generator is running, or an APU is being used. While the electronic elements of the turret are warming up, physically check all of the gear within the turret for security, paying special attention to units such as the cameras, the guns, the sight, the controller, and the feed mechanisms. Remove any securing device that may have been installed. If the flight is to be strictly gun camera exercises, assure that the guns and ammunition are in safe condition.

The following steps indicate the procedure for performing an operational check on a typical electric turret:

Check the gunfire interrupter system by moving the turret in azimuth and the guns in elevation with the controller handles. Insure that the system interrupts the gunfire or causes the guns to clear all aircraft structures during the time that the "dry runs" are being made. Also insure that the limiting devices function properly so that no structural damage will result from firing.

1. ***Warning:*** Be sure that the guns are not loaded.
2. Visually inspect the ammunition to insure that the cans are loaded and that the rounds and links are oiled and free to allow the belted ammunition to be flexible.
3. Check the operation of the controller handle grips with power OFF to see if there is any binding, and that they are tight on their mounting shafts. Close each action switch to insure that both will start the motor-generator.
4. Test the operation of the turret by displacing the controller handles and checking the movements of the turret in azimuth and elevation for smoothness and ready response to all controller handle displacements. In one series turret set the gun selector switch to IND (Individual), and close the right-hand trigger switch. Listen

for the right-hand gun firing solenoid to operate in the percussion primed ammunition guns. Perform this same test with the left-hand trigger. Reset the gunfire selector switch to BOTH and again test trigger switches. Now either trigger switch should operate both the right- and left-hand solenoids. Turn the switch to the OFF position and assure that the solenoids function when the trigger switches are depressed.

5. Operate the turret and depress the guns against their down limits and hold them there with a slight pressure on the controller handles. ***Caution:*** Do not hold the guns at their stops too long.

6. Rotate the turret at low speed in azimuth and ascertain that the guns do not strike any portion of the aircraft structure. Make a similar check with the guns as high in elevation as they will go. Energize both elements of the sight lamp and check the optics for cleanliness.

7. Check the structure interrupter system by moving the turret in azimuth and the guns in elevation with the controller handles. Insure that the system causes the guns to clear all aircraft structures during the time that the "dry runs" are being made. Also, insure that the limiting devices function properly so that no structural damage will result from firing. The checking of the gunfire interrupter system is not simple enough to be performed as a preflight check.

8. Run the reticle image rheostat through its entire range from dim to bright, and set it at the most comfortable brilliancy.

9. Check and energize the oxygen and intercommunication systems.

10. Inspect the plexiglass for cleanliness and damage.

11. Inspect the spent case and link stowage for security.

After the above procedure has been carried out, the turret is ready to operate. The guns may now be loaded when the combat area or the firing range is reached.

The above check may be made on the ground before takeoff, or in the air during flight. The turret will be vacated during takeoffs and landings.

Maintenance

TURRET ELECTRICAL SYSTEMS.—To maintain a turret in good working order requires a planned daily maintenance schedule be carried out. The electrical system of the aircraft turret requires its share of this maintenance work. All electric motors, such as the motor-generator and others employing brushes, will need frequent checks for condition of the brushes. These carbon elements are subject to damages from heat, arcing, vibration, and other destructive forces and require frequent inspection. As soon as a brush shows chipping or undue wear, it should be immediately replaced. Due to the fact that there is a great deal of vibration from the aircraft as well as from firing of the guns, a great many electrical connections of the turret are subjected to becoming loose. Should such happen, high resistances will occur at the connections.

Naval aircraft are persistently operated near and over water and in areas where the relative humidity is high. Such places are conducive to corrosion of metals, therefore the entire electrical system should be checked for evidences of corrosion on contacts, connections, busses, resistors, etc. Heat is also a great factor in the deterioration of many electrical system components. For this reason, frequent checks should be made for overheated wiring, insulation breakdown, cracked resistors, breakdown of shielded wires, shorts due to excessive heat, distorted switch cases (bakelite), and for other sources of heat damages.

Circuits are designed to carry prescribed voltages. Turret components are designed to work on prescribed voltages. Voltages that are higher or lower than prescribed have a damaging effect on the circuits and components. Low voltages will cause relay chattering, faulty operation of the components, overtaxing of resistors, and many other difficulties. Lower voltages than pecified will cause more trouble than higher voltages, ecause when the power surges, circuit breakers will rotect the circuits and components. However, when oltages are too low, there is little that may be done to revent damages except to shut off all current and track own the cause or causes.

There are numerous items which should be checked or security and condition within the electrical system f the aircraft turret. Some of these points to check are security and condition of all AN connectors; correct caacity of all circuit breakers; condition of the turret mergency switch; armament safety relays for proper unctioning; electronic tubes for strength of emission nd gas content, functioning of the heater circuits, and esponse for purpose designed; condition of all variable esistors; clearness and gain of the intercommunications ystem; and finally, all the components of the turret hould be checked by performing an operational test of he turret.

The chances of having to rewire the complete turret re remote. This is seldom necessary even during maor overhaul at the overhaul activity. However, it does ecome necessary at times to replace certain wires, witches, relays, resistors, circuit breakers, motors, and ther components. The bulk of this type work may be ccomplished at the operating activity (squadron) level. t is therefore necessary that the squadron personnel ssigned to work of this nature be thoroughly trained n this area.

TURRET MECHANICAL SYSTEMS.—Maintenance work on he mechanical features of the turret requires that checks nd inspections be made at periodic intervals the same s with any other mechanical device. The aircraft turet is subjected to vibrations from the firing guns and hose transmitted to it from the aircraft in which installed. Precautions must be exercised to insure that all nechanical components and elements of the turret are secure and in good condition.

One of the most frequent causes of trouble with mechanical devices is improper and/or lack of lubrication. It is, therefore, essential that all the mechanical components of the electric turret be lubricated in strict accordance with the instructions for the turret concerned. It will be noted from the lubrication chart of the turret concerned that it is about as damaging to overlubricate in certain instances as not to afford sufficient lubrication. This is particularly true of electric motors.

It would be impractical to consider here all of the items of mechanical nature which require maintenance in a study course. Detailed instructions on this maintenance work are contained in the specific *Handbook of Maintenance Instructions* for the turret concerned. However, some of the items of the turret requiring preventive maintenance at specified periods and the work to be accomplished are as follows: Turret drive motor brakes should be checked for proper actuation; controller checked for lubrication with the specified materials; security of all turret components including the guns should be checked; check all safety gear such as oxygen equipment, seat and shoulder harness (if installed) for security and condition; insure that the intercommunications equipment is stowed in place; check the feed mechanisms of the guns and the boosters with their associated chuting and ammunition cans for security and distortion; check the working condition of the azimuth and elevation control clutches; check the azimuth and elevation gear sectors for distortion and missing teeth; check the turret drive motor bevel (or spur) gears for condition. Turrets should be exercised frequently in elevation and azimuth under power.

Check to insure proper functioning of the turret positive manual locks if installed. Manually displace turret to check for backlash in the gear trains. Inspect the skin of the turret and the plexiglass for distortion, cracks, and transparency. Operate all gun chargers (with master switch deenergized on types where this is possible) to check functioning. Check action of hydraulic and pneumatic pressure switches where installed. Check unctioning of booster motor switches. Check security f armor plate and bullet resistant glass. Check the turet ball bearings and their races and the trunnions for wear and security. Check operation of turret smoke oors; inspect the turret frame members, castings, and urfaces for distortion. Inspect all working parts of the urret for proper and sufficient lubrication, and finally, heck the turret interior for cleanliness and neatness.

Tests

TURRET ELECTRICAL SYSTEMS.—For running tests on omponents of the electric turret, a great variety of test equipment is needed. It will be necessary to use meggers, ohmmeters, continuity tester, ammeters, oscillographs, oscilloscopes, analyzers, vibrometers, variable ransformers, dynamometer generators, audio oscillators, nsulation breakdown testers, a stabilization test unit, microvolters, stroboscopic tachometers, and other units. Some of these units are used in the test of the motor-generator, while others are used in testing other components of the turret. There is a good possibility that special test rigs will have to be made up in addition for tests for which no specific pieces of test equipment are available. No one squadron or activity will normally possess or have access to all of these testing units and may not even be in a position to procure them. This necessitates the development within the activity of the necessary testng equipment in many instances. Ordinarily, this equipment may be manufactured locally from plans shown in the *Handbook of Service Instructions* concerned.

One of the more important tests of electric turret components is testing of the motor-generator unit. The instructions given below for this test are included as an example of a complete test of a turret component. Naturally, it is not necessary to commit this test to memory as like instructions are always given in the publications for the turret concerned.

In performing the test on the motor-generator, it is necessary to remove this unit and install it on the test

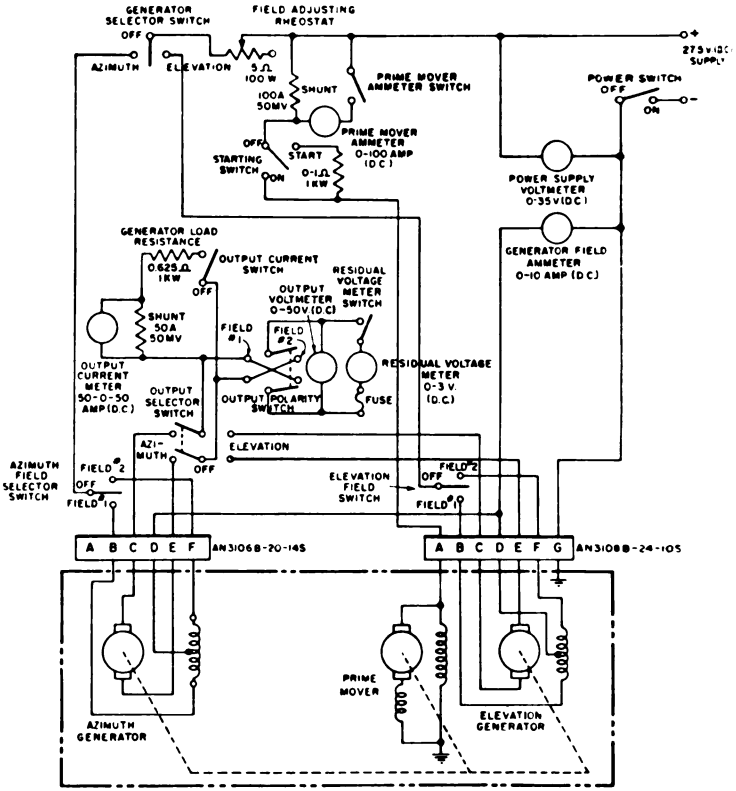


Figure 6—5.—Motor-generator setup.

equipment. (See fig. 6–5.) Set the power supply switch to ON and the starting switch at first to START then to ON (or RUN). The direction of rotation of the motor-generator should be clockwise as seen from the azimuth end.

Allow the unit to run unclamped for a while and measure its vibration with a vibrometer, or other equally suitable instrument. Insure that the vibrations at the bearings, measured perpendicular to the axis of rotation, are less than 0.001 inch r.m.s. (The r.m.s. denotes root mean square which in itself is a measurement of the mean amplitude of the vibration or the square root of the mean, or average, square.) In other words, if a vibration is present as shown by the meter of more than 0.001 inch r.m.s., it is cause enough for the motor-generator to be sent to overhaul. Check the polarity of the elevation generator by placing the selector switch of the generator on ELEVATION, putting the elevation field selector switch to FIELD #2, placing the output selector switch on ELEVATION, and placing the output polarity switch on FIELD #2. At this point the output voltmeter should read upscale. Next, place the elevation field selector switch on FIELD #1. The output voltmeter should still read upscale.

To perform the test for the azimuth generator, place the generator selector switch on AZIMUTH, the azimuth field selector switch on FIELD #2, the output selector switch to AZIMUTH, and the output polarity switch on FIELD #2. The output voltmeter should again read upscale. Next, turn the azimuth field selector and output polarity switches to FIELD #1. The output voltmeter should read upscale. Finally, turn the generator selector switch to the OFF position.

To conduct a NO-LOAD TEST OF THE PRIME MOVER, turn to the ON position the prime mover ammeter switch, and with the frame temperature at 38° C. (110° F.) check the speed of the armature with a stroboscopic tachometer. The speed should be between 9,850 and 9,100 r.p.m. The voltage during this test should be 27.5 volts, plus or minus 0.1 volt. Check the prime mover ammeter to insure that it is not reading over 43 amperes, and turn to OFF the ammeter switch.

During the following NO-LOAD TEST OF THE GENERATORS as well as the test for residual voltage, periodically inspect the commutation. Sparking should not be immediately noticeable upon starting, nor upon close inspection should the sparks have a bluish tint. First, turn the generator selector switch to AZIMUTH, the azimuth field selector switch to FIELD #1, and the output polarity switches to FIELD #1. Also, the output selector switch should be placed on AZIMUTH. Move the field adjusting rheostat until the generator field ammeter indicates 4.5 amperes, plus 0.1 or minus 0.0 ampere. The output voltmeter should indicate 45 volts minimum. Turn the generator switch to OFF. Depress the contact switch to read the meter. The residual voltage should not exceed 0.4 volt. Place the azimuth field selector and output polarity switches to FIELD #2, and the generator selector switch to AZIMUTH. See that the generator field ammeter indicates 4.5 amperes, plus 0.1 or minus 0.0 ampere. Adjust the field adjusting rheostat so that the output voltmeter indicates 45 volts minimum.

Turn the generator selector switch to OFF and check the output voltmeter reading. This reading should not exceed 0.4 volt. Position the elevation field selector and output polarity switches to FIELD #2, and the generator selector switch to ELEVATION. Move the field adjusting rheostat until the field ammeter indicates 4.5 amperes, plus 0.1 or minus 0.0 ampere. The output voltmeter should indicate 45 volts minimum. Place the generator selector switch to OFF, and with the residual voltage meter, insure that there is no more than 0.4 volt indicated.

To conduct the FULL-LOAD TEST OF THE PRIME MOVER turn the output selector switch to AZIMUTH, the azimuth field selector and output polarity switches to FIELD #1. Place the prime mover ammeter and generator load switches to the ON positions. Turn the generator selector switch to AZIMUTH, and move the field adjusting rheostat until the generator field ammeter reads 4.5 amperes. The output current ammeter and the output voltmeter shall read 90, plus or minus 2 amperes and 26 volts minimum, respectively. Using the stroboscopic tachometer, determine and record the r.p.m of the generator. Record the input voltage from the power supply voltmeter. Record the input amperage from the prime mover ammeter. Record the field amperes from the generator field ammeter. Turn the azimuth field selector and output polarity switches to FIELD #2. Adjust the field current to 4.5 amperes as was done

the first part of the full-load test, and record the same
ta in the order given. Now turn the generator selec-
and azimuth field selector switches to the OFF posi-
n, and the elevation field selector switches to FIELD
. Place the output selector switch to ELEVATION,
d turn the generator switch to ELEVATION. Regu-
e the field adjusting rheostat until the generator field
meter reads 4.5 amperes. Record the same data as
fore.

Turn the generator selector switch to the OFF posi-
n. Place the elevation field selector and output po-
ity switches to FIELD #1. Turn the generator
ector switch to ELEVATION, and adjust the field
rrent to 4.5 amperes and record as before. Turn the
wer supply and generator selector switches to their
F positions. The speed of the prime mover shall be
00 r.p.m. minimum with a 38° C. (100° F.) frame
nperature. The input voltage, as read from the power
pply voltmeter, shall be 27.5 volts, plus or minus 0.1
lt. Input amperage, as read from the prime mover
nmeter, shall not exceed 225 amperes. The generator
ld amperage, as read from the generator field amme-
r, shall not exceed 4.5 amperes, plus 0.1 or minus 0.0
npere. Turn off all switches and disconnect the motor-
nerator from the test circuit. Replace all screens and
vers.

TURRET MECHANICAL SYSTEMS.—In order to move
eely throughout all its arcs, the turret must be rig-
ly supported by friction-free devices. Some turrets
e mounted to the aircraft through trunnions in which
ll or roller bearings provide ease of movement. Others
e supported by circumferential ball races encircling
e turret and in between which run either metal or
astic balls retained at proper intervals by spacers.
he guns are normally mounted on trunnions which are
tached to a frame. This frame is rotated in elevation
nd depression by the elevation drive system of the tur-
et. There is a great variance in the manner in which
rrets and their armament are supported and attached

to the aircraft. Each of these methods is an attempt to make it possible for the turret to perform its basic function in the most expeditious manner possible in its location within the aircraft for which it is designed.

Periodic tests of the various mechanical features of the electric turret resolve themselves into inspection problems. The mechanical features are ruggedly designed and precisely manufactured to perform their several functions. However, it is necessary to test and inspect any mechanical device because constant wear, stresses, and atmospheric conditions have damaging results. Some of the tests to be made in and about the electric turret are as follows:

Inspect the turret entry doors and hatches for freedom of operation, fit, lubrication, and condition. It is important that these devices do not drag, rub, or otherwise bind, thereby hindering turret operation or impeding the operator's escape from the turret in an emergency.

The turret power sliprings (where installed) along with the ball bearings, roller bearings, ball races, and other devices which support, mount, and confine the turret should be tested and inspected periodically for operation and condition.

The azimuth and elevation clutches, both manual and those associated with the drive motors, should be checked regularly for ease of engagement and disengagement, wear, and general condition. Also test the drive motor brakes for effectiveness if installed.

If emergency mechanical sights are installed, test them for operation so that they will be ready and effective when and if needed.

Test the movements of the guns (elevation and depression) and insure that the gun slide slots in the plexiglass portion of the turret do not exhibit excessive wear and looseness. Also check that the armor plate and bullet-resistant glass are properly installed and secure.

Test the mechanical parts of the foot range pedal and the hand controller assemblies for freedom of operation.

Test the mechanical limit stops of the turret (where nstalled) by operating the manual controls. Inspect he structural interrupter mechanical parts for alignment and wear, and check the timing of the interrupter. Make the necessary adjustments by means of the incororated timing pins.

Operate the gun chargers, whether hydraulic or pneumatic, by activating the necessary power units and ycling the chargers. They should act quickly without elays caused by friction, faulty pressures, or binding.

Test the action of the ammunition boosters with the mmunition clear of the boosters. The boosters of one eries turret should operate when a strain is placed on he spring-loaded micro switch, and should deenergize he boosters when the tension is released. While in this physical area, the ammunition chuting should be checked or clear undistorted paths from the ammunition cans, hrough the boosters, to the guns. Check the chuting or excessively sharp bends, and misalignment of its ndividual segment. Check security of the cans, boosters, and feed mechanisms. Expended link chutes should also be checked to insure that the links have an indisturbed path to the discard.

Mechanical actuation of the turret smoke doors should be checked. When actuated, these doors should smartly and fully open; and when closed, they should close ompletely.

Turret drive motor and transmitter drive gearing hould be periodically inspected for tooth wear, alignment, mesh, and general condition, to insure that none will fail.

All self-locking devices and safety items should be hecked and tested for security and functioning. Self-ocking nuts, safety wiring, and such items as leg guards and mechanical gun safeties are the items to be covered.

After boresighting and harmonizing the guns, all components affected in this work should be checked for security.

All switches, circuit breakers, relays, and trouble lights should be inspected for mechanical failures, incipient or real.

TESTING THE COMPLETE INSTALLED TURRET.—Whenever an electric turret has been newly installed, been reinstalled after overhaul, or some major component has been replaced, the operation of the entire turret should be tested with the power supply. A test of the turret such as follows will generally suffice. However, some turrets will necessitate variations to the instructions below for complete testing. Although several of the individual circuits and mechanisms of the turret drive system will not specifically be mentioned in this discussion, it is understood that they all contribute their important parts to the overall operation of the turret. The discussion that follows is essentially an operational test of the turret.

After having properly entered the turret, secured all loose gear, insured that the guns are properly cleared and adjusted the safety belt, then turn the master switch to its ON position. Turn ON the fire control equipment also so that it may warm up for the specified time, depending on the ambient temperature. While these units are warming up, check out the intercommunications system and the oxygen system. By this time the time delay relay will have actuated, thus permitting testing of the stabilization system.

With the prime mover operative, the generators are ready to function. Having progressed this far in the operational check of the electric turret, all that remains to be done is to check for the proper operation and functioning of the following components, units, or elements of the turret as described elsewhere in this chapter: drive motor brakes; drive motors (elevation and azimuth); azimuth and elevation limit stops; gun solenoids and gunfire interrupters; fire control equipment; rotational speed (degrees per second); gun cameras; gunsight cameras; boosters; searchlight (when installed); gun charger controls and safety features; indicator lights (where installed); trouble lights; and circuit breakers which should be checked before and after flights.

RESTRICTIONS IN TESTING.—There are certain tests which may have to be conducted on electric turrets that are normally beyond the capabilities of the operating activity. For this reason they are usually assigned to an overhaul facility. The equipment available to the operating activity, the trained personnel available, and other factors will enter into the decision as to whom should be entrusted with the testing of the turret, at least the more complicated aspects of testing. This decision will ordinarily be made at the local level.

Repairs

TURRET ELECTRICAL SYSTEMS.—In the operating activity in which there is a well-planned and aggressively promoted preventive maintenance program, actual repairs to the electrical components of the turret will be always at a minimum. This fact has been borne out many times. Conversely, where proper preventive maintenance work is not practiced, there is forever a necessity for making repairs or replacing components. When the turrets are new and in top working order, then is the time to put into effect a vigorous preventive maintenance program. This done, repairs and replacements will be few and far between.

It is inevitable, however, that some repairs will have to be made to the electrical components as time goes on. This type of repair work often resolves itself into a job of replacing components rather than making actual repairs to the components themselves. For example, in the event that a relay, resistor, circuit breaker, some wiring, a condenser, or other elements become faulty, it is usually more expeditious and economical to replace the component itself rather than attempt to repair or replace the faulty element. Availability of replacements will play a big part in any decision to be made in such a situation. It may be that procurement of a replacement part or component would involve so much time that it would be a great deal more effective to repair the faulty element of the component. Of course, this is the other side of the picture, but the situation does exist at times when it pays to repair, even if personnel from another division has to be brought in to accomplish the work. However, the existing local conditions will dictate the correct answer to the problem in arriving at a decision in most instances. Factors in arriving at such a decision will involve logistics, expenditures necessary to effect repairs, priority of the job, availability of replacements, location of nearest overhaul activity, and a determination as to whether or not the component should be repaired or survey. Material aid may be derived from certain instructions which govern the decisions to be made in the repairing or surveying of specified components. They should be consulted.

In order to repair electrical components of the turret (if such a decision has been reached), it is necessary to have the proper test equipment available. These instruments will determine to a great extent the actual source of trouble, as well as the amount of wear, damage, degree of faultiness, and other general troubles existing within the components. Although test equipment is invaluable in troubleshooting and repair of the electrical system, visual inspections should not be omitted. Often this type of inspection will immediately determine the cause of trouble by bringing to light visible damages, wear, overheating, misalignment, breakage, and other difficulties. Therefore, test equipment should not be used to the total exclusion of visual inspection.

Some types of troubles occurring within the electrical systems of the turret may manifest themselves before any appreciable damage is done. For instance, if the intercommunications system emits static noises during operation of the turret in azimuth, it may be an indication that the collector brushes or a loose connection thereon are arcing, the commutator is dirty, or that the brushes are badly worn. There are many other indications familiar to the experienced maintenance personnel which suggest certain troubles as well as bringing to mind immediately the necessary remedial actions.

TURRET MECHANICAL SYSTEMS.—There are possibly more repairs to be made, at the operating activity level, on the components of the turret of a mechanical nature than of an electrical nature. Here again, mechanical repairs should be limited to those which may be effected with the tools and other equipment available to the activity. Control linkages, mounts, adapters, controls, certain bearings, metal skin surfaces, plexiglass surfaces, fittings, connectors, and chutes are some of the items which may be repaired locally to varying degrees if not completely. Once again, it is quite often more expedient to replace the unit rather than make repairs.

However, when it becomes necessary to make certain repairs, or when it is clear that repairs are well within the capabilities of the squadron, all efforts should be made to rectify the situation locally. Control linkages become damaged and may be repaired quickly if found to be bent or broken. Worn, broken, or misaligned camera mounts may be repaired or manufactured locally. Controller handles may be freed if they are found to bind. Although the needle, taper, and ball bearings found in the turret are fabricated as complete units and may not be repaired when damaged, there are other bearing surfaces such as the ball races (ring gear) and ball bearings of the turret which may be repaired if not damaged too extensively. Structural Mechanics may be called in to repair abrasions, tears, and distortions of the turret fairings and skin. The plexiglass sections of the turret may be reconditioned and repaired.

Fittings, in general, may be repaired, or new ones fabricated locally when the necessity arises. Drive motor connectors sometimes break. It may be possible to repair the connectors with the means at hand. Ammunition chuting is subjected to a great deal of wear and damage as it curves away from the cans to the boosters, and then to the guns enclosing the heavy belted ammunition. It is possible in most types to repair the chuting by replacing the broken or damaged segments of the chuting. Other types have to be replaced.

Backlash in the turret supports may be rectified by adjustments to certain cams, or by adding or taking out shims. Broken or worn manual turret control drives may be repaired by replacing the damaged links in the chains. The reflector glass in the optical gunsight may be replaced when necessary. There are many other such items which are partially or wholly repairable in the electric drive turret, but most of these are familiar to the First Class and Chief Aviation Ordnanceman.

RESTRICTIONS IN MAKING REPAIRS.—Aircraft turrets are relatively new equipment to the Navy, having made their appearance during World War II. They are so new and their construction so complex with various controls that the responsibility for maintenance and repairs to the turret may be switched among various rates from time to time. Furthermore, maintenance and repair on the operating activity level is not currently firm among the various rates whose qualifications require that some of their duties involve work on the turret. The AQ, AO, and AE, all are to varying extents responsible for maintenance and repairs to the aircraft turret.

When trouble develops in components of the electric drive turret, the operating activity will attempt to make the necessary repairs with the equipment and personnel available. If it is seen that the job is beyond the capabilities of the activity, the next logical step is to request the supporting FASRon for the necessary tools, equipment, and possibly personnel. If the FASRon is incapable of making the repairs either through lack of proper personnel or equipment, a decision must then be made as to whether or not it is more advantageous to survey the components, or return them to the nearest specified overhaul activity. In the meanwhile, the operating activity may have made replacements of the components in the turret unless it was unable to procure them. Both the squadron and the FASRon may have to fabricate certain pieces of test equipment for their own use, as some of it is not even carried in the ASO system.

Squadrons, and even FASRons, would hardly be capable of making repairs to turrets such as mending (welding) a broken or cracked turret frame. This type of repair would be left to the overhaul activity designated for this class of repair. It might then be said that the operating activity is expected to make only routine repairs to the turret and its components. The definition of the word "routine" is more or less left up to the commanding officer who will establish, as conditions warrant, the limits to which his personnel may go in making repairs to the turret as well as other equipment.

Alignments

TURRET ELECTRICAL SYSTEMS.—The electrical components of the electric drive turret have to be aligned periodically and whenever they are replaced, repaired, or otherwise altered. In the electric turret, the major alignments to be made usually concern such components as: controls of the motor-generator; structural interrupter; gunfire interrupter; gun chargers (sequence of charging); gunfiring controls; stabilization gear; turret drive system; and all electrical brushes and cables.

It will be necessary to use various instruments and tools (specialized in some cases) in order to make certain of these alignments. In others it will be necessary to have only the basic hand tools in order to make the alignments.

As an example of the procedures involved in making alignments to various electrical turret system components, one or more routine types will be discussed. In performing a brush test insure that the brushes are seating 100 percent in the direction of rotation, and at least 75 percent along the axis at right angles to the direction of rotation. Generally speaking, these values are for the prime mover and other electric motors. Generator brushes should show seating of at least 75 percent of their total surface areas to be in good working order. The pressure exerted on the commutator by the brushes should be within the range indicated in the instructions for the particular piece of gear involved. This is usually somewhere between 9 and 14 ounces. To check for brush holder pivot friction, measure the force necessary to just lift the brushes off the commutator and the force on the brush as it returns to the commutator. Generally, this difference should not be over ¼ ounce. Brushes should be spaced 90 degrees apart (plus or minus about 1/32 inch); the brush edges should be parallel to the edge of the commutator bar, and should be about 1/32 inch within the outside edge of the commutator.

If, during the brush test, even one of the brushes shows defects, replace ALL brushes in the unit. Make sure that brushes being replaced bear the correct stock numbers.

The INSULATION RESISTANCE TEST is begun by disconnecting all ground connections from the frame before making the megger test. Use a 500-volt megger (d-c) and test the motor-field to the frame, and the motor-armature to the shaft. On the azimuth and elevation generators, test the field to frame, the armature to shaft, and the armature to fields. The resistance measured should be in the neighborhood of 1.0 megohm minimum.

TURRET MECHANICAL SYSTEMS.—The turret mechanical system components have to be aligned and realigned occasionally. Major work on these components consists of alignments to boresight targets and screens; gunsights and turret; bombsight and turret; guns with gunsight; azimuth and elevation gearing; manual control drive chains; seat locking assembly; motor and generator armatures with their fields; ball bearings with their races; armor plating and bullet-resistant glass; gun components; feed mechanisms; ammunition link and ammunition chutes; ventilation system; electrical contacts, and others.

As an example of the procedures in making mechanical

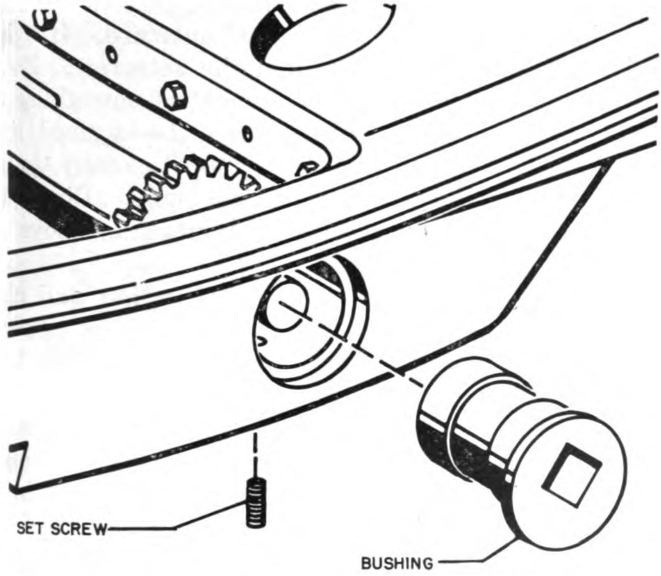


Figure 6–6.—Elevation backlash alignment.

alignments to components of the electric drive turret, the following will illustrate a few routine types:

ELEVATION BACKLASH may be aligned in one series turret by placing the turret in manual drive and positioning it in its azimuth and elevation zero position. (See fig. 6–6.) Use a straightedge and scribe a line across one of the fixed and one of the rotating gear rings at or near the front gun mount casting. The setscrews in the bottom of the drive housing are loosened. These setscrews hold the backlash adjusting bushing, and their threads in the housing are peened over. Rotate the eccentric bushing on each side of the turret and cause a movement of more than 1/32 inch displacement between the scribed lines when pressure is applied at the gun barrels. Rotate one of these bushings, in making the above displacement, until the displacement between the scribed lines on the fixed and rotating rings is moved 1/32 inch as measured with a scale when up and down pressure is applied to the gun barrels. Check the bushing to insure that it has not moved outward. If it has, tap it back in place and tighten the setscrew. Rotate the other bushing until a displacement of something less than $\frac{1}{32}$ inch is measured between the scribed lines. Back the bushing off very carefully until exactly $\frac{1}{32}$ inch in movement is measured with the scale. Check this bushing for possible outward movement as above and tighten the setscrew.

Manually position the turret in elevation and check the backlash at several different positions by applying pressure to the gun barrels. After both eccentric bushings have been adjusted, the square holes in the heads of the bushings should be aligned in the same direction. Thus, if the square hole in the right-hand bushing is offset towards the front of the turret, the hole in the left-hand bushing should likewise be offset towards the front. Peen over the threads above the setscrews when the alignments have been completed.

GUN MOUNT ALIGNMENT, or realignment, is found to be necessary in the front mounts due mainly to wear in the lands of the front mount clamp rings and the rings on the guns. Long use causes this wear which prevents the rings from locking together properly when the guns are installed. (See fig. 6–7.) The rear gun mount adjustments are provided for boresighting only and are not disturbed for any other reason. When adjustment and alignment are found necessary for the above reasons, proceed as follows:

All play between the rings may be removed by adjustment and alignment of the front gun mount sockets. With the guns in their proper positions and the front gun mount locking levers in the locked position, loosen the self-locking nuts which secure the retaining rings to the front gun mount supports sufficiently to permit rotation of the sockets. Rotate the right-hand front gun mount socket in a counterclockwise direction (looking from the gun muzzle) until the gun is correctly locked in place. Rotate the left-hand front gun mount socket

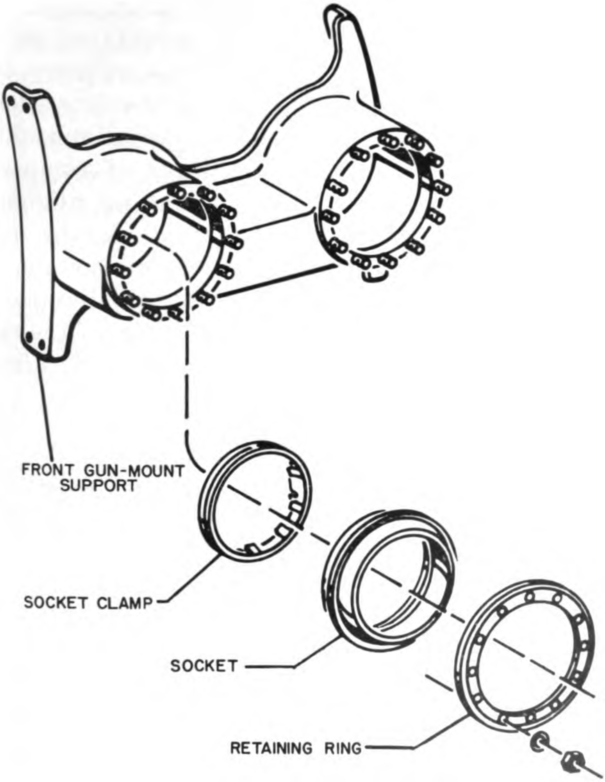


Figure 6–7.—Gun mount alignment.

n a clockwise direction until the gun is locked correctly n position. Then tighten the self-locking nuts on the tuds of the front gun mount support. This action ecures the retaining rings. After the slack or play ias been removed it will be necessary to boresight the uns.

RESTRICTIONS IN MAKING ALIGNMENTS.—There are a umber of alignments which may be made to the elecric drive turret by the operating activity. However, here are other alignment procedures which are normaly outside of the capability of the average activity due o its lack of the necessary tools, testing equipment, and authority to perform some of these procedures. For this reason, the operating activity would not be concerned with adjustments and alignments to turret bearings of most types, silhouette cams of the interrupters, gears and gear trains, gyroscopes, jig alignments of various materials, and other procedures of comparable complexity. Another restriction in making alignments is that the alignments to be made shall not be undertaken except during the proper time intervals and time periods. For example, it would be highly inopportune to attempt an alignment of some component of the turret during flight. Any alignment should be made after or before flight.

Electric Turret Stabilization System

PRINCIPLES OF OPERATION.—Were the turret to be mounted on a STABLE platform, accurate aiming of its guns could be obtained by using only the basic drive circuits of the turret. It is appreciated that the aircraft in flight offers no such stable platform since it is continuously subjected to outside (extraneous) forces of pitch, roll, and yaw, as well as to accelerated turning moments. It, therefore, becomes necessary to stabilize the turret's position in space in order that the aim of the guns will not be disturbed by these extraneous aircraft movements. This function is performed by the stabilization gear and circuits, which are closely related in function to the basic drive circuits containing two similar channels. One of these is for azimuth and the other for elevation.

Two gyroscope assemblies are mounted within the turret. They are similar and are composed of a single-degree-of-freedom gyroscope whose gimbals are mechanically coupled with a torque motor which is similar to the receivers in the controller. These gyroscopes are also connected to E-transformer armatures. They differ only in the orientation of their respective gyroscope wheels. The assemblies are mounted in the turret so that azimuth movements of the turret cause precession of the azimuth gyroscope and elevation movements of the turret cause precession of the elevation gyroscope. Azimuthal movements have no effect upon the elevation gyroscope and vice versa.

To follow the operation of the stabilization gear, only the elevation channel stabilization circuit will be discussed. This is because the elevation channel discussion applies equally to the azimuth channel except for one difference which will be discussed later. When an elevation rate is established by displacement of the controller handles, the turret moves at the rate indicated and the transmitter on the elevation drive motor produces a signal which is proportional to the rate of turret movement. The output of the transmitter, in addition to being applied to the controller and structural interrupter receivers, is also applied to one winding of the torque motor in the elevation gyroscope. This velocity control signal produces a torque at the output of the torque motor which is proportional to the turret rate. Since the gyroscope is a rate type, it tends to precess an amount proportional to the rate of turret movement, and therefore produces a torque at its gimbal proportional to the turret rate. The gyroscope precessional torque and the torque output of the torque motor are equal and opposite.

Since both torques act on the gimbal, they are algebraically added and produce no displacement of the gimbal. Any extraneous elevation movement of the turret, such as those caused by pitch, roll, and yaw movements of the aircraft, is algebraically added to the rate produced by the drive motor. Thus, the precessional torque of the gyroscope is proportional to the elevation rate of the turret. This results from the algebraic addition of the rate produced by the drive motor and any extraneous rate provided. The torque output of the torque motor is always proportional to the rate produced by the drive motor. This results (when the torques are algebraically added) in the gimbals being displaced by an amount proportional to the extraneous turret movements only. Any displacement of the gimbal produces a like displacement in the E-transformer armature which is also mechanically connected to the gimbal. Displacement of the E-transformer armature generates a signal in the output windings of the unit; the phase of the signal being determined by the direction of armature displacement. The E-transformer output signal is proportional to the turret rate error.

The E-transformer output signal is applied to a servo amplifier circuit where it is amplified and converted into a d-c servomotor control signal. The polarity of the signal is determined by the phase of the turret rate error signal. The servomotor turns in the direction indicated by the polarity of the control signal and drives the stabilization potentiometers and a tachometer. These potentiometers are excited by 28 volts d.c. and their arms are driven in opposite directions by the servomotor; one towards the 28 volts, the other towards ground. These potentiometers perform an integrating action, producing an output that is proportional to the position error caused by the extraneous turret movements. They are connected into the transmitter-receiver circuit in such a manner that their output is algebraically added to the velocity control signal. Thus, the velocity control signal applied to the controller receiver is modified by the stabilization signal, increasing or decreasing the speed of the drive motor as required to compensate the turret for the extraneous movements. This action stabilizes the space position of the turret.

Rotation of the servomotor drives the tachometer which produces a signal proportional to the speed of the servomotor rotation. This signal is applied to the second winding of the elevation gyroscope torque motor, and serves as a stabilizing feedback to counteract the torque of the first winding produced by the change in the velocity control signal, which results from the addition of the stabilization input. As previously noted, the azimuth channel stabilization circuit's function is

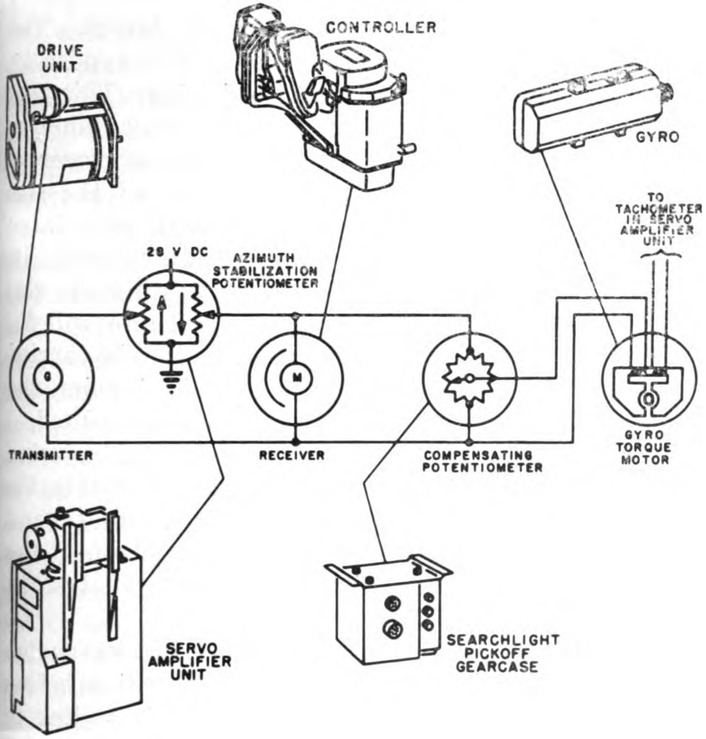

CONTROLLER
DRIVE UNIT
GYRO
TO TACHOMETER IN SERVO AMPLIFIER UNIT
28 V DC
AZIMUTH STABILIZATION POTENTIOMETER
G
M
TRANSMITTER
RECEIVER
COMPENSATING POTENTIOMETER
GYRO TORQUE MOTOR
SERVO AMPLIFIER UNIT
SEARCHLIGHT PICKOFF GEARCASE

Figure 6—8.—Azimuth stabilization channel compensation circuit.

similar to that of the elevation channel, but with the following exception. The elevation movements from the zero elevation position decrease the sensitivity of the azimuth gyroscope so that it precesses an amount proportional to the cosine of the elevation or depression angle of the turret.

In order to obtain correct stabilization in azimuth, the velocity control signal (which excites the azimuth gyroscope torque motor) must be decreased proportionally. A compensating potentiometer performs this function. (See fig. 6–8.) It is driven by the output of the turret elevation drive. This potentiometer is specially designed and is excited by the velocity control signal, producing a signal which is a function of the cosine of the elevation or depression angle of the turret. The output of the compensating potentiometer is applied to the azimuth gyroscope torque motor winding. This provides the input required to produce the correct stabilization output at the azimuth gyroscope E-transformer.

MAINTENANCE AND TESTS.—Maintenance of the stabilization system of the turret will depend to a large extent on the results of testing afforded the system. In other words, the results obtained from testing the stabilization system with the stabilization test unit will determine the extent of the maintenance work to be carried out. Proper use of this test unit will pinpoint the troubles and remedial actions are thereby expedited.

The stabilization system of the turret should be tested by rigging the proper stabilization test unit within the turret. First, position the guns to zero azimuth and elevation with the controller (or manual controls if the turret is not activated) prior to running the test on the azimuth drive with the test unit.

Caution: Make certain that the turret master switch on the control junction box is in the OFF position before connecting the test unit. Do NOT move this switch to the ON position as long as the test unit is connected to the drive.

Connect the turret power cable to the input receptacle on the test unit, and to the suit heater of the turret. Turn the inverter power and stabilizer switches on the servo amplifier panel to INVERTER POWER and STABILIZER, respectively, and allow one minute for warmup. Turn the selector switch to ROLL and the test unit power switch to the ON position. Hold the meter switch ON and observe the meter needle swing. Turn the adjustment knob, if necessary, to cause the meter needle to swing to the red markings on the scale. Release the meter switch and turn the power switch to the OFF position. If adjustments cannot be made, obtain another meter before proceeding.

In order to test for a NULL INDICATION, connect the test unit output cable to the TEST SIGNAL OUTPUT jack and to the desired azimuth or elevation test unit input jack on the servo amplifier. Turn the selector switch to the desired model error, which is the null reading position. This switch is selective so that the proper model error may be set up in the test unit. The null position for all electric turrets now in use is the same—E1061 error. Hold the meter switch to the ON position and observe the meter. If the needle is off the zero setting by more than two divisions, remove the servo amplifier cover, or the azimuth and elevation coarse adjustment covers, loosen the locknut on the proper coarse potentiometer (azimuth or elevation), and carefully adjust until the meter reads within two divisions of zero. In the event that this position cannot be reached through adjustment, refer to the applicable maintenance section of the drive handbook.

To test the RESPONSE INDICATIONS, turn the selector switch to the desired model error and the test unit power switch to ON. Hold the meter switch at ON and observe the total meter needle sweep. Maximum sweep shall be 20 scale divisions, from one extreme to the other, irrespective of the zero setting position. If the total sweep is more than 20 divisions, refer to the proper service and maintenance handbooks. Tighten the potentiometer locknut and replace the covers.

Turret Ventilation Systems

For every type of aircraft turret, there is a different type of turret ventilation system. This is understandable when it is realized that each manufacturer designs his own, and that for each type of turret there are differing design problems. The function of all types of ventilation systems is to scavenge undesirable fumes, smoke, and vapors from the turret so that the operator has an obstructed vision and a healthful environment in which to work. The most important reason for ventilation of turrets is to eliminate gas which causes explosions within the turret.

The firing of guns inevitably produces gases of combustion which escape from the breeches into the turret. In sufficient quantities these fumes and gases are toxic in addition to forming an atmosphere within the turret which reduces visibility noticeably if not properly eliminated. Most turrets have a system of air scoops incorporated which, when opened, cause ram air to enter. In conjunction with the scoops, there are smoke elimination doors which are automatically opened when the gun switch on the control junction box is energized. Ram air enters through the scoops and forces the contaminated turret air out through the elimination doors. In this type of system it is necessary to have curtains or doors which make the turret more or less airtight. In this manner, the ram air produces a pressure differential within the turret which readily eliminates the bad air through the only readily accessible exit, the smoke doors. As long as the guns continue to fire, this ventilation process continues. The scoops close when firing ceases, but the smoke doors, in most installations, are purposely delayed in their closing in order to more completely scavenge the contaminated air.

There are many variations as previously stated in turret ventilation design. Some turrets incorporate hot air manifolds which fuurnish heated air to the turret from the aircraft's engine(s). This air aids in pressurization of the turret for purposes of smoke elimination. There is a butterfly valve in this manifold to control the airflow. Others simply rely on the ram air scoops to perform this function of smoke elimination.

ELECTROHYDRAULIC DRIVE TURRET SYSTEMS

Theory of Operation

The electrohydraulic turrets used by the Navy are normally uninhabited, but locally controlled. That is, the operator sits outside of the turret ball in a compartment directly adjacent to the ball. The ball alone has movement in azimuth and elevation. The sighting head is geared directly to the ball and moves proportionally with the ball movements. Turret movements are caused by displacements of the controller handles. Power for moving the turret is furnished by a hydraulic power assembly. The units within the assembly are operated by solenoids which are connected to the potentiometer controls in the controller.

The azimuth dive of this type turret rotates the turret by means of the azimuth gear train. This transmits the mechanical rotation from the azimuth drive hydraulic motor to the azimuth drive pinion. The pinion then meshes with the gear sector. The ball portion of the turret is suspended on two ring bearings (trunnions), and the gear sector is attached to the turret ball so that the ball moves in either direction in response to the azimuth pinion rotation. The turret ball is limited in rotation by a mechanically controlled limit system which receives its control from an antiference mechanism located on the controller. The antiference mechanism returns the controller potentiometer wiper arms to the center position as the turret ball approaches its limits, thereby stopping the turret.

Elevation movements of the turret ball are produced by rotation of the two halves of the ball about the circular center structure as a complete unit. The elevation drive motor drives the turret through precise gearing to the sector gearing. Limits in elevation and depression are controlled the same as those for azimuth—by the antiference mechanism.

The electrohydraulic turret is actually controlled by three systems: an electrical system, a hydraulic system, and a mechanical system. A series of follow valves in the hydraulic system provides control of hydraulic power for operation of turret. They are controlled by electrical signals generated by controller displacements and are amplified to increase the current which operates the hydraulic control valves. The hydraulic system obtains its motive power from a constant-speed electric motor and is thus indirectly controlled by the electrical system. Hydraulic pressure produced by the pump connected to the electric motor produces rotation of the two turret drive motors. These drive motors (elevation and azimuth) operate the turret mechanically through gear trains. Each of the above basic systems of operation is directly or indirectly controlled by the sensitive valves whose actions are modified by the amplification system. This insures that the turret is completely responsive to all controller handle movements.

The manual drives for azimuth and elevation control are connected to their respective drive systems by power clutches. These controls may be connected or disconnected at will, and are generally used for positioning the turret for servicing and repairing.

The electrohydraulic turret power system is utilized to convert constant-speed mechanical rotating motion into hydraulic power and then reconverting it to mechanical motion in order to perform the required work. Although the power drive motor operates at constant speed thus turning the hydraulic pump at constant speed, hydraulic volume delivered by the pump is variable and may be increased or decreased when desired. In order for the turret drive motors to run in both directions of rotation, it is necessary to have a means of reversing the direction of fluid flow through the motors. A special feature takes care of this function—the servo control valve assembly.

HYDRAULIC SYSTEM.—Two hydraulic variable-displacement PUMPS within the hydraulic power unit are known as A-ends, and the two fixed-displacement MOTORS which drive the turret in azimuth are known as B-ends. Displacements of the controller handles actuate follow valve assemblies which cause the power pistons to move the A-end pumps off their neutral (no pumping action) position. This action in turn creates a directional pump-

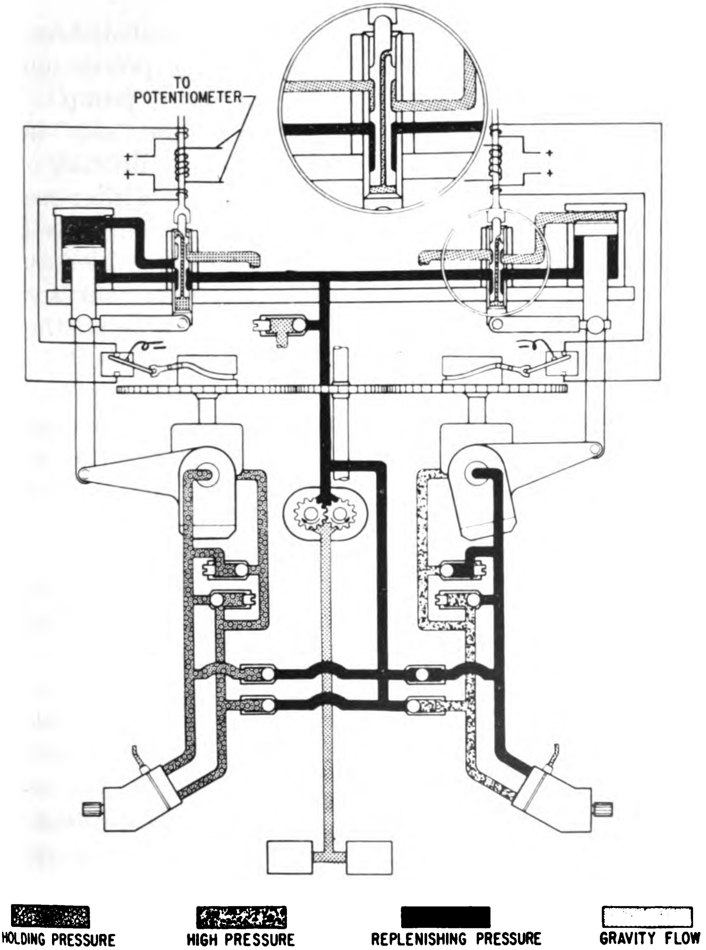


Figure 6–9.—Hydraulic power unit schematic.

ing action in the A-end pumps by effecting a displacement of the A-end pistons. When the A-ends are displaced from their neutral positions, the resulting pumping action sends hydraulic fluid to the B-end motors, thus driving the turret in azimuth and elevation. Reversal of the displacement of the A-ends sends the fluid in the opposite direction to the B-ends, thus causing them to run in the reverse direction. (See fig. 6–9.)

The hydraulic system incorporates a replenishing element which keeps hydraulic fluid in the power unit at a constant level through a low pressure pump. This action takes care of the inherent hydraulic "slip" in the system and assures that no flat spots or bubbles occur to cause the drive to work unevenly. A dither mechanism is also incorporated. This mechanism sets up a constant minute vibration within the follow valve assemblies which does not allow the frictional surfaces to actually come to absolute rest against one another at ANY TIME even though these valves may not be operating. These minute vibrations are generated by mechanical action from cams, or electronically through the aid of a thyratron tube mechanism. This action serves to reduce to an amazing degree the friction that is found in starting to move one surface at rest over another at rest.

ELECTRICAL SYSTEM.—The 28-volt d-c or 115-volt a-c electrical system of the electrohydraulic turret is much like that of the electric turret system, although not as elaborate due to the fact that much of the work performed by electricity in the electric drive turret has been taken over by hydraulics in the electrohydraulic turret. Actuation of the master switch of the electrohydraulic turret energizes such elements as the amplifier, action relays, one pole of the FIRE-SAFE gun switch, gun heaters, time delay relay heater, indicator lights, gun camera relay and heater, gunfiring relay contacts, and others. As in the electric turret, there are elements and components which draw their power from a point ahead of the master switch and relay such as the suit heater, trouble lights, boresight switch and gunsight lamp, loading switches, and certain thermal circuit breakers.

MANUAL OPERATION.—Power clutches engage and disengage the manual drives of the electrohydraulic turret. Each of the handcranks is connected to its respective drive system by means of these small power clutches.

When the manual drive handles are connected, a direct mechanical connection between the hydraulic drive motor and the drive pinion of its respective system is afforded. Manual controls may be used in an emergency to train the turret, and for making movements of the turret in azimuth and elevation while performing maintenance work on the guns or turret.

GUNS AND FEED MECHANISMS.—The normal armament of the electrohydraulic turret is two 20-mm guns. These guns may either have hand chargers or pneumatic chargers and may fire either electric primed ammunition or percussion primed ammunition. They are installed within the turret by means of gun mounts to mounting brackets as ordinarily found in other 20-mm gun installations.

The feed mechanisms of the guns for the electrohydraulic turret are either pneumatic or spring driven units which are employed as best adapted to the particular installation involved. If a source of compressed air is readily available, it is possible that both the feed mechanisms and the gun chargers will be of the pneumatic type. Otherwise, these components may be spring driven and manual, respectively.

SAFETY DEVICES AND CONTROLS.—The electrohydraulic turret is fitted with several safety devices and controls which eliminate, as far as is possible, the dangers from mechanical and electrical failures as well as those normally contributable to human error. The heater element of the time delay relay prevents the turret from becoming operable until after the amplifier has had sufficient time to warm up sufficiently to operate successfully. Thus, the turret cannot be made to operate wildly which it would do if operated before the amplifier had warmed up. There are limit controls for azimuth and elevation which prevent the turret from being forced beyond its established cone of fire, thereby damaging the turret and other structural components. This is accomplished by the antiference mechanism mechanically returning the potentiometer wiper arms to the center position. This action equalizes the current in the azimuth and elevation solenoids. The electrical system is provided with circuit breakers, condensers, and other types of safety devices for the protection of the system. Even the hydraulic system has its safety devices such as snubbers, relief valves for the hydraulic pump and for the system as a whole.

OPERATIONAL CHECKS.—After proper entry into the electrohydraulic turret and insuring that all switches, valves, and components are in their correct positions, an operational check may be made. Unless the flight is for the purpose of making gunnery runs, the guns should all be clear of ammunition.

A routine operational check might be as follows:

Inspect the guard rails for the protection of the operator's legs. Check all visible hydraulic lines for leaks, or indications of leaks. Elevate and depress the operator's seat and see that it locks securely at any desired position. Test the operation of the azimuth and elevation handcranks. Check for visible evidence of torn, chafed, or otherwise damaged wiring in the turret. If the flight is a gunnery hop, check the operation of the gun chargers by charging each gun a complete cycle with the guns pointing in a safe direction.

Warning: Perform the following checks with the guns UNLOADED. Some of these checks will have to be made prior to entering the turret.

Check the feed chuting, boosters, and the feed mechanisms for security of all components. Inspect the turret ball weather seals for damage, and the transparent canopy for cleanliness, scratches, cracks, and crazing. Make sure that the oil level in the reservoir at the base of the pneumatic compressor (if installed) is at the correct height, and drain the pressure tank by removing the plug at its base. Check the condition of the sight control unit by inspecting the mechanical operation of all control knobs. Check the operation of the range control (foot) to insure that it returns to its upper limit position. Visually inspect the intensity of both sight lamps, and move the control knob (dimmer knob or rheostat) to insure that the brilliance of both the lamps varies evenly. Clean the sight lens and filter glass. Check mechanical operation of the action and microphone switches and talk to another operator at a remote station to test the intercommunications system. Turn the master switch to ON and test the FIRE-SAFE and camera switches. The camera should run when either gun camera toggle switch is depressed.

Plug in and test the heated suit, or check the receptacle for proper voltage with a test lamp. Finally, operate the turret throughout all its movements with the controller handles at slow speed at first, and then if this test proves satisfactory, slew the turret through the same movements to insure that it operates correctly at high speeds.

MAINTENANCE, TESTS, REPAIRS, AND ALIGNMENTS.—In carrying out routine maintenance, tests, repairs, and alignments on the electrohydraulic turret, a similarity will be noted to the same work on like components and elements of the electric turret. Many of the electrical components of both turrets are identical and their functions comparable. Some of the components common to both are cameras, boosters, indicator lights, circuit breakers, boresight systems, suit heaters, compressors, pressure switches, voltage regulators, electric prime movers, and others. These will require roughly the same type of work to be performed on them. However, there are other electrical components which are peculiar to each type of turret and which require differing types of work. As an example, the electrohydraulic turret has a dither mechanism, solenoid valves, and a completely different method of balancing its amplifier.

There are normally specific periods of time and/or usage at which aircraft turrets receive scheduled maintenance. Quite often these periods are made to fall on or coincide with the normal operating check periods of the aircraft itself, i.e., 60-, 90-, and 120-hour checks. Alignments, repairs, tests, and routine maintenance are conducted during these checks. There will naturally be times between these specified checks in which work will have to be accomplished on the turret in order to keep it in top operating condition. Some of the work performed on the electrohydraulic turret is as follows:

Adjustment to the hydraulic power unit is usually restricted to adjusting the pressure within the replenishing pump system. It is important to maintain this pressure at or near the recommended setting, otherwise the operation of the hydraulic power unit as a whole is seriously affected.

Excessive backlash in the azimuth drive system may be caused by two factors. There may be too much clearance between the teeth of the azimuth drive pinion and rack, or as a result of accumulated clearances in the gear box of the azimuth drive assembly. If it is the latter cause, special methods to be found in specialized instructions will have to be consulted. If, however, excessive backlash is caused by the former factor, adjustments and alignments may be made relatively easy with the proper hand tools and a feeler gage.

Excessive backlash in the elevation drive is caused by improper meshing between the elevation drive pinions and the elevation ring gear segments. To rectify this situation requires disassembly of a greater part of the turret, which is not ordinarily done at the operating activity level.

The function of the hand control assembly is to house the controller and antiference mechanism. Mechanical linkage within the box automatically returns the control potentiometer slides to neutral position when a limiting position is reached, regardless of controller handle position. This method of antiference control assures smoothly decelerated stops and eliminates the need for mechanical limit stops. The antiference mechanism is checked for alignment by visually inspecting the indicator lines

a the ends of the azimuth and elevation pan guides with
spect to the index lines of the inspection windows lo-
ted at the base of the hand control housing. If these
arks are in perfect alignment in both the azimuth and
evation windows, no alignment will be necessary. If
ese marks do not align, adjustment may be made by
anipulation of the splined shafts and sprockets of the
imuth and elevation drives. The azimuth drive as-
mbly supports the sight yoke, which mounts the sight
ead and the elevation sight unit.

Adjustment of the turret controls becomes necessary
hen the turret fails to remain stationary while the
ontroller handles are in neutral. This indicates that
he solenoid control valve assembly linkage is out of
lignment, or the amplifier is out of adjustment. It
ust be determined which adjustment is to be made.
lways make the mechanical adjustments to the control
lve assembly first. Disconnect the amplifier from the
rcuit by pulling out the circuit breaker. Touch the
tion switches and note the amount and direction of
reep. If the turret does not move, it means that the
alve assembly is properly adjusted and the trouble is
ost likely in the amplifier. If the turret does move,
he following adjustments are necessary:

1. For azimuth adjustment remove plug #1 from the
ickers power unit. For elevation adjustment, remove
lug #2.
2. Turn follow valve screw #1 on the Vickers power
nit.
3. Tap the side of the housing to free the dither mech-
nism.
4. Touch the action switches.
5. If creeping movement is SLOWER, continue the ad-
ustment in the same direction. If creeping movement is
ASTER, turn the follow valve screw in the opposite
irection.
6. Continue adjustments until mount assembly has no
movement.

7. Use follow valve screw #2 for making elevation adjustments.

Alignment of the amplifier is conducted with a d-c voltmeter and tools to make adjustments to the azimuth and elevation balancing potentiometer screws. Adjustments are made so that the turret will stop any movements that were noted as the turret drifted off its neutral positions of azimuth and elevation during the original tests. Proceed as follows in making the necessary adjustments:

1. Zero the mount.
2. Electrically balance the control potentiometers by means of the test jacks on the amplifier chassis.
3. Holding the elevation handcrank in the energized position, touch the action switches. DO NOT MOVE THE CONTROL HANDLES.
4. Note the movement of the mount assembly in azimuth. Zero the mount after each adjustment.
5. Make adjustments on the azimuth resistor.
6. Touch action switches to check for proper direction of adjustment.
7. Continue to adjust azimuth resistor until no movement occurs.
8. Release elevation handcrank.
9. Use same procedure on elevation resistor until mount assembly remains stationary.

NOTE: If maximum adjustment of the resistors does not stop the electrical creeping, check the tubes in the corresponding circuit.

The range control pedal is adjusted by operating the pedal from long to short range and vice versa while watching the sight reticles reflected on the combining glass and checking the range position indicator on the range unit dial window. The range position indicator should respond precisely to any movement of the range pedal. Adjust the stop screws so that the pedal may not travel more than the prescribed number of degrees past the maximum range reading.

The azimuth and elevation units are aligned by an ohmeter. The turret is moved slowly by manual drives in azimuth and elevation while readings are noted from the ohmeter. These readings should be infinity for a symmetrical number of degrees about the zero position before the ohmeter needle begins to register up on the scale. The adjustment is to get the infinity ohmmeter reading to exactly bracket the zero positions of the azimuth and elevation units. The azimuth and elevation units are shifted around on their bases until the correct adjustments are made.

Repairs have to be made occasionally to the plexiglass canopy, metal skin surfaces, and structural members of the turret. Each type of such repairs are covered in great detail in the pertinent *Handbooks of Maintenance and Service Instructions* and need not be discussed here.

The hydraulic system of the turret incorporates relief valves which may be adjusted so that optimum pressures may be set up within the system. There are also relief valves which have preset relieving pressure values built into them and they have to be replaced when any variance occurs.

The A-end pumps have to be tilted at just the correct angle from their neutral positions to deliver the exact amounts of fluid to the B-end motors called for by the displacement of the power piston. The linkage system from the power piston to the A-ends must not have extraneous movements caused by wear. Alignment of the linkage system has to be checked periodically.

A continuing check must be made for hydraulic leaks throughout the hydraulic system of the turret. Careful inspection may even bring to light incipient leaks in which tubing and high pressure hose are being chafed, or minute cracks are forming. The replenishing system takes care of internal leaks (slippage) of the hydraulic system, but leaks to the outside of the system through damaged seals, packing, fittings, and at other points will have to be detected and eliminated immediately.

High pressure systems, such as the hydraulic system of the turret, require frequent checking to assure satisfactory operation.

As has been previously shown, the dither mechanism is actuated by either a mechanically vibrated system of cams and lever arms, or by an electronic device incorporating thyratron tubes and other elements. There is an electronic dither device for each of the two servo control valve assemblies. The thyratron tubes function to create minute alternate energizing of the dither coils which produce the oscillations of the solenoid armatures of the servo control valve assemblies. In the event that a thyratron tube becomes damaged or internally shorts out, these minute vibrations will cease and no longer will the turret be able to commence any movement in azimuth or elevation without exhibiting jerky motions. Replace the tubes if such motions begin to become evident during operation of the turret.

The constant-speed motor of the hydraulic power unit should receive a 27.5-volt d-c or 115-volt a-c (whichever is being used) power supply to operate properly. The power to the turret must be constant at all times during operation. The brushes of this motor must exhibit proper seating on the commutator; 100 percent seating in the direction of rotation and at least 75 percent seating along the axis at right angles to the direction of rotation. Damaged brushes should be replaced when inspection shows chipping or poor contact.

The electric gunfiring circuit will be checked at intervals to insure that there is no wire chafing; loose connections; overheating of the transformer, the FREE-SYNCH switch, gunfiring relays, etc. The gun chargers (manual, hydraulic, and pneumatic) should have their alignment checked frequently. The hydraulic type should be checked for leaks, misalignment of the unit or the gun, alignment of the actuating mechanism with the bolt of the gun, and for general condition with regard to wear of frictional parts. The pneumatic type should be checked for about the same conditions as they are both basically alike—the major difference being the driving medium.

Restrictions in making repairs, tests, and alignments o the electrohydraulic turret are about the same as for he electric turret. The previously mentioned restricions under which the operating activity finds itself, with egard to lack of all the necessary tools and equipment with which to accomplish the above work, apply here as well.

Safety Precautions

TURRET OPERATION AND MAINTENANCE WORK.—The aircraft turret, like any other piece of machinery, can be a hazard to the operating personnel as well as those working in and around it. The turret even has an added hazard in that it contains two powerful guns.

Upon entering the turret, the operator should observe all regulations concerning entry. He should not use the gunsight as a handhold lest this important unit becomes misaligned or broken. He should place the proper foot nside the turret first, then carefully pivot his body inside by taking hold of the turret structure and swinging the other leg in last. This is the proper entry method for at least one type of turret. As a preflight check of the turret safety devices, connect the suit heater, don the oxygen mask, adjust and fasten the safety belt, and adjust the gunner's seat to the proper working height for flight. Legs should be outside the leg guards and eyes level with the gunsight. All these features will then be in readiness for use upon climbing back into the turret after takeoff. A thorough check of the interior of the turret for articles adrift should be made as a precaution against possible jamming of controls. Each set of instructions covering a particular turret gives detailed information on adequate safety precautions. These will be read and thoroughly understood before attempting to enter and operate a turret.

Very seldom is it necessary to make adjustments to a turret while it is in operation to clear up some malfunction. Normally, there is enough testing equipment within the activity to perform trouble shooting while the turret is inoperative. Adjustments and repairs to the turret should be made with the proper tools and equipment, otherwise damages may result.

Swing the guns in both azimuth and elevation to their limits to insure that they (or other parts of the turret) do not strike the aircraft fuselage. This test should be made whether or not the turret is equipped with mechanical limit stops or electrical limiting feature. It usually requires the operator and an assistant to perform this test satisfactorily.

GUN PRECAUTIONS.—Most Aviation Ordnancemen have read safety precautions for aircraft guns so many times they either know them by heart or they have become numbed to their real meaning and application. Only a tragedy or near tragedy will awaken a person to precautions in this event. Safety precautions are promulgated, for the most part, because of some damage or fatal accident which has happened. If the ordnanceman will only remember this fact, he will not allow himself to become hardened to the warnings set up at such a cost Some of the more important safety precautions are repeated here to refresh the minds of those whose job it is to work with guns and turrets:

1. Never load turret guns unless ready to fire them Loading will then only take place on approaching the gunnery range, combat area, or after all preparations have been made for test firing them into the butts.

2. Always keep fingers and tools clear of the gun breech mechanism. If the bolt should accidentally go forward, fingers would be mutilated and tools would damage the mechanism.

3. Never disconnect the pressure supply on pneumatic or hydraulic chargers without first having relieved the pressure. Men have been blinded by high pressure air and fluid.

4. Hangfires and misfires should be treated in strict

ccordance with the published instructions issued by the ureau of Ordnance and repeated in other Navy safety recautions. Whenever a gun does not fire after the ormal firing device has been operated, it must be conidered that a hangfire exists in the gun. Repeated fforts may be made to fire the gun by depressing the igger switches, but the breech of the 20-mm guns ust not be opened (by operating the chargers) sooner an 10 seconds after first attempting to fire the rounds. owever, the rounds should be cleared from the chamber ot later than 45 seconds after this time to prevent posible "cook-off" of the rounds if the guns are hot. Be ure to check the instructions for the guns involved with egard to removing unfired rounds.

5. Guns may become dangerous to fire if they are not roperly cleaned of corrosion in the chamber and barrel.

6. Although it is necessary to keep a film of oil in the arrels between firing periods, it is necessary to remove his oil before firing the guns. Excessive chamber presures have resulted from gases generated from the oil y heat of firing when they were added to the pressures eveloped by the combustion of the powder.

7. The barrel chambers have to be polished at regular tervals to prevent the rounds from binding on being ithdrawn from the chamber during firing.

8. It is necessary to fit tompions in the ends of the arrels after cleaning to insure that the bores will reain clean and corrosion free. Enough rust and corroion may accumulate in the bores if not protected by he tompions to rupture the barrels were the guns to e fired in this condition.

9. If guns are to be stored or otherwise not used for ny appreciable amount of time, the bolts should be let orward into battery. This will take most of the comressional forces off the drive springs and prolong their seful lives.

10. Both ammunition and links of the 20-mm guns hould be lubricated in the amount and with the special ype oil called for in the pertinent instructions. This is

necessary so that the rounds may be cycled into and extracted from the gun chambers without binding. The links have to receive this same oil also so that they will be delinked from the ammunition without trouble. The clearance between the unfired rounds and the barrel chamber walls is slightly exaggerated in the 20-mm gun. As the round is fired, the case expands evenly to completely fill the chamber. If the chamber is pitted, eroded or its surfaces otherwise irregular, and the ammunition is not lubricated, there is a good possibility that the round will not be extracted. The extractor may even rupture the spent case pulling only part of it from the chamber. In either event there will be a stoppage.

11. Do not become so familiar with ammunition that proper handling precautions are subconsciously overlooked. No matter how often repeated, it is still none the less true that, "Familiarity breeds contempt." General laxity in observance of safety precautions can ultimately lead to only one thing—DISASTER. Treat 20-mm ammunition as if it were all of the explosive type.

12. During delinking of belted ammunition, separate the various types of rounds and stow by type so it will not become mixed when it is again belted.

13. When making gunnery runs remember the incendiary effect of your fire on dry grass and flammable materials.

14. Never carry belted ammunition over the shoulder. Fake it out in the boxes during transportation. It is very easy to twist or stretch the links if the belt is mishandled, thereby causing stoppages later on when used.

15. Turn off all gun switches when loading or unloading ammunition into or from the aircraft.

16. Keep all ammunition stowed in the aircraft or the ready magazine and do not allow any of it to become adrift. "Souvenir hunters" relish unattached rounds of ammunition and may even permanently injure or kill themselves, and others, in attempting to deactivate the round by clumsily attempting to remove the tetryl loaded projectile, the powder, and the primer.

17. When loading the ammunition into the guns, careully avoid striking the primers on any sharp object or orner, and make sure that the belts do not become inked or twisted.

18. No smoking can be permitted in areas in which mmunition is being handled or stowed.

19. It is repeated that all 20-mm ammunition, in genral, should be treated as if it were high explosive inceniary (HEI) and the dangers of ammunition handling ill be reduced to a minimum.

20. When there is any doubt concerning safety preutions for guns and ammunition, consult *United States avy Safety Precautions*, OpNav 34P1, and all related ublications issued by the Bureau of Ordnance, and turet safety precautions issued by the Bureau of Aeroautics. Never be in doubt longer than it takes to find nd study the above publications!

Turret safety.—As with all safety precautions, the es applicable to turret safety are commonsense items. commonsense is lacking, so also is safety. In returnng from a gunnery flight, the guns should be made safe nd the turret secured while flying over sparsely poputed areas. There is always the ever-present danger of advertently firing one or more guns when clearing em. This important detail should never be left unone until nearing the home field or other thickly poputed areas.

The turret operator is not allowed to remain within e turret during take offs or landings. This means that e operator will have to be completely sure that his guns re safe and that the turret is secure before the aircraft kes off and again before he leaves the turret prior to nding. Ordinarily, the squadron policy will concretely utline the step-by-step procedure for loading, unloadng, and safetying the turret guns. The turret operator ill normally see to it that the proper amount of amunition is in each can and is of the correct type for e flight coming up. He will also check the operation f the guns and chargers, but not allow the guns to become loaded in so doing. And finally, he will check the operation of the turret and its general physical condition.

A routine safety check of the turret and its guns after flight is as follows:

1. Visually inspect the chamber and feed mechanism of each gun to insure that they are empty of ammunition. If not possible to see directly into the breech, feel inside the feed throat, breech opening, and chamber.
2. Check the feed chutes and boosters for ammunition and remove any rounds remaining there in accordance with squadron doctrine.
3. Move the turret either by controller or handcranks to its zero positions of azimuth and elevation and secure in this position with the devices incorporated.
4. Turn off all switches and other sources of power, such as compressed air and hydraulic fluid.
5. Empty all spent case and link containers (if incorporated) and remove all ammunition cans for either rearming or stowing.
6. In cleaning and oiling the guns, assure that they are never pointed in an unsafe direction regardless of the fact that they may be unloaded.
7. Charge the guns through a complete cycle with the feed mechanisms unloaded and the gunfiring switches OFF. If any malfunction shows up, correct it immediately and let the bolts forward with care before securing the turret.

CLEANING AND CLEANING SOLVENTS.—Cleaning of the guns and turret components is as important as seeing that the turret is armed and ready for service. Without constant attention to the cleaning problem, the turret, in general, rapidly deteriorates, and may even become useless as a weapon.

Precautions concerning general cleaning and cleaning solvents are as follows:

1. Have absolute knowledge that the solvents to be used are the correct ones. The specifications of the solvents have to match the job to be done as there is no all-purpose solvent for general cleaning of the many dif-

erent materials of which the turret and guns are comosed.

2. There will be no smoking in or near the turret beng cleaned with solvents.

3. The turret will have to be adequately ventilated hile using solvents inside because moderate concentraions of vapors given off by certain of these materials re toxic. (CARBON TETRACHLORIDE IS NOT TO BE USED.)

4. Hands and exposed areas of the body should be ashed with clear water and soap immediately after ontact with solvents.

5. Remove and destroy all oily and solvent-soaked rags fter use to prevent possibility of spontaneous combusion.

6. Clean and polish all plexiglass surfaces with clear ater and a recommended soap. Wipe dry with a lintree cloth which is completely free of grit.

7. A vacuum cleaner may be used to advantage in leaning out the interior of the turret. Insure that the ower line to the turret is not chafed and cut on sharp dges within the turret.

8. Never use solvents on plexiglass or allow it to even ome in contact with this transparent material. Most f these solvents will cause crazing of the material.

9. It is safer to make use of the manual controls on he turret when necessary to rotate the turret in azinuth and elevation while cleaning.

10. When cleaning and relubricating the turret gears, he proper cleaning materials must be used and relurication performed with the correct specification oil or rease.

11. Insure that fingers and cleaning rags are clear of ll gears while the turret is being rotated.

12. An accumulation of oil and grease within the turet indicates damage, wear, or malfunction of some comonent or tubing of the turret. Make a careful inspecion before cleaning up the oil or grease in an attempt o find the exact location of the leak.

13. After cleaning any electrical contacts, insure that they are wiped clean and dry and that all abrasive particles have been removed.

14. An oil base cleaner should be used when cleaning surfaces not protected by paint or other protective finishes.

15. When cleaning hydraulic filters or changing cartridges of the filters, look for foreign materials trapped therein. Often this will give an excellent indication of incipient or actual failures of components of the hydraulic system.

16. When cleaning out hydraulic lines, accumulators, and components, it is best to flush them out with the same type of hydraulic fluid as is used for operating purposes.

17. It is essential that hydraulic fluids of different types NOT be mixed or used interchangeably in the same system without complete flushings in accordance with current directives on this subject. The different types are not compatible with one another and form a totally unusable and injurious product when mixed.

General cleaning of the aircraft turret should be a regularly established part of the preventive maintenance program for the turret, with daily cleaning of certain portions of the turret an added responsibility.

QUIZ

1. Turret guns are charged
   a. pneumatically
   b. manually
   c. hydraulically
   d. by all of the above

2. The lead arising from the relative motion between the firing aircraft and the target is called
   a. ballistic lead
   b. kinematic lead
   c. lag time
   d. none of the above

3. Releasing the action switches on all turrets causes
   a. the control handles to return to neutral
   b. the turret to return to the home position
   c. only the sight to become inoperative
   d. the turret to stop

4. The profile interrupters prevent the
   a. turret from overtraveling its limits
   b. guns from firing into aircraft
   c. turret from traveling too fast
   d. guns from firing too fast

5. The number of seconds set into the time delay feature of the stabilization system is approximately
   a. 10
   b. 20
   c. 30
   d. 40

6. Corrective voltage from the stabilization system is placed into the turret's
   a. transmitter-receiver circuit
   b. generator control circuit
   c. generator drive motor circuit
   d. transmitter structural interrupter torque motor circuit

7. The turret transmitter is a permanent magnet generator that creates a voltage in proportion to the
   a. speed of the motor generator
   b. speed of the servomotor
   c. limit of turret movement
   d. speed of turret drive motor

8. The purpose of the stabilization system is to stabilize the turret by
   a. stabilizing erratic outputs from motor generator
   b. stabilizing the r.p.m.'s of the turret drive motors
   c. stabilizing the transmitter output
   d. eliminating any roll, pitch, or yaw of the aircraft

9. The smoke doors on the turrets will open when the master switch and
   a. FIRE-SAFE switch are closed
   b. action switch are closed
   c. trigger switch are closed
   d. smoke door switch are closed

10. In order to boresight the turret sight, the following switches must be closed
   a. master and action switches
   b. master and sight switches
   c. master and boresight switches
   d. boresight switch only

11. The turret generators are
   a. compound wound
   b. series wound
   c. split field wound, separately excited
   d. parallel wound

12. The turret prime mover is
   a. series wound
   b. compound wound
   c. shunt wound
   d. none of the above

13. The switches that are a pertinent part of all control handle assemblies are the action, trigger,
   a. master, and microphone
   b. microphone, and gun
   c. master, and gun
   d. and microphone

14. The SYNCH position of the FREE-SYNCH switch indicates that
    a. the booster motors will run simultaneously with the guns
    b. the firing pins are in parallel with each other
    c. both guns must be in battery in order to fire
    d. none of the above

15. The structural interrupter prevents the
    a. guns from firing into the aircraft
    b. turret from traveling too fast
    c. guns from firing too fast
    d. guns from striking fuselage of the aircraft

16. The structural interrupter torque motor (or motors) is excited by the output of the
    a. motor generator
    b. transmitter
    c. servo tachometer
    d. receivers

17. The type of operation common to present day nose turrets is
    a. observation
    b. searchlight
    c. gunnery
    d. all of the above

18. Turrets are equipped with manual controls in order to
    a. position turret for boresighting
    b. position turret for routine maintenance
    c. remove a casualty
    d. all of the above

19. The stabilization test meter is used to check null, response, and
    a. roll
    b. speed
    c. zoning
    d. noise

20. The null position of the stabilization test meter for all electric turret drives is
    a. E1041 error
    b. E1043 error
    c. E1061 error
    d. E1063 error

21. The antiference mechanism prevents the
    a. guns from firing into the aircraft
    b. turret from traveling too fast
    c. guns from firing too fast
    d. guns from striking the fuselage of the aircraft

22. The hydraulic pumps (A-ends) are characterized by
    a. constant speed, constant displacement
    b. variable speed, constant displacement
    c. constant speed, variable displacement
    d. constant speed, fixed angle of tilt

23. The turret hydraulic system is prevented from damaging overloads by
    a. check valves
    b. snubbers
    c. relief valves
    d. all of the above

24. If the turret creeps when the control handles are in the center position, the unit which needs adjustment is the
    a. antiference mechanism
    b. solenoid control valve
    c. replenishing pump
    d. limit cam

25. The dither mechanism is operated either
    a. pneumatically or hydraulically
    b. hydraulically or mechanically
    c. mechanically or electronically
    d. manually or electronically

CHAPTER 7

SUSPENSION, ARMING, AND RELEASING SYSTEMS

The coverage of suspension, arming, and releasing systems in this chapter is intended for the leading petty officers who have previously studied the details of the various components of these systems. A discussion of the component parts of the suspension, arming, and releasing systems was afforded coverage in *Aviation Ordnancemen 3 & 2,* Volume 2, NavPers 10346. Further detailed information on these components may be found in the pertinent publications of the Bureau of Ordnance, the Bureau of Aeronautics, and from various other sources.

The schematic block diagrams presented in this chapter do not depict any one particular installation of suspension, arming, and releasing systems. They do show COMPOSITE arrangements of all circuits and devices likely to be found in any one aircraft type classification. It will be well to remember this point while studying the various systems below.

Drastic changes to the aircraft carrier in the form of greater tonnage, angled decks, steam catapults, more speed, and others have been matched by aircraft of greater speed, weight, and capabilities. Both the aircraft and carrier bear little resemblance to their World War II counterparts. Even their tasks and tactical employment have been subjected to sweeping changes. It is as though a new Navy had been born since VE day.

Greater airspeeds have made guns less effective, new rockets and missiles have replaced guns in certain instances, and new sighting devices have increased the number of "hits" per round carried. A look at current naval aircraft shows that new armament stores have (1) necessitated new types of racks and shackles, (2) brought about production of more rugged suspension devices, (3) forced the employment of ejector racks for satisfactory supersonic releasing of stores, (4) introduced in smaller aircraft provisions for suspending and delivering nuclear weapons, and (5) reduced the necessity of multiple gun installations in aircraft.

Internal suspension of armament stores in aircraft is limited to the larger naval aircraft. There is little room in wings or fuselage of the smaller aircraft, as these spaces are devoted to components of the aircraft and fuel storage. Stores that were formally carried internally in certain aircraft are now carried externally. Some of the old racks and shackles have been redesigned to meet new demands. New racks and shackles have been produced to suspend, carry, and eject new type stores and components such as electronic navigational packs (NavPacks). Turbine air starters are being placed in pods which are externally suspended. Stores to be carried externally at present day speeds have to be streamlined to present the least resistance to airflow. Therefore, bombs, fuel tanks, and many other items carried externally are rapidly taking on highly streamlined shapes.

Since the modern jet fighter is smaller, heavier, and infinitely faster than earlier ones, many changes have become necessary in suspension, arming, and releasing devices now associated with them. The attack and patrol classes of aircraft are reaching top speeds formerly attributed only to the jet fighters and are able to carry and deliver many times the armament loads. Their devices are similar to, and in many cases identical to, those of the fighter. The attack and patrol classes, however, incorporate diversified internal configurations. Within a short period of time they may be converted to mine layers, fuel tankers, bombers with conventional stores, bombers with special weapons stores, bombers for training purposes loaded with practice bombs, photographic reconnaissance aircraft, and other configurations.

The armament circuits, which supply power to the new and redesigned racks, shackles, and other devices, have been modified to an extent necessary to adapt them to the new features of these devices. They are normally actuated both manually and electrically as before. The manual releases are still relatively simple in design, but the electrical releasing circuits have been complicated to a great extent by addition of new circuits to operate the stores ejectors, monitoring systems for special weapons, new rack and shackle operating circuits, and other presently incorporated features.

TYPICAL FIGHTER AIRCRAFT SYSTEM

The suspension, arming, and releasing system shown in figure 7–1 indicates two separate power sources—28-volt d.c., and 117-volt, 3-phase, 400-800 cycle a.c. The a-c power is supplied through a voltage regulator which controls the output of the generator (or inverter) at 117 volts, plus or minus 5 volts. The a-c power is used for operation of the radar and other components while the d-c power is employed to operate the control features of the aircraft, including armament and fire control components. The 3-phase a.c. is made available from three separate buses usually labeled "A," "B," and "C," or "1," "2," and "3." The regulator for the d-c power controls this current at 27.7 volts, plus or minus 0.5 volt.

There are numerous buses for delivery of power located throughout the aircraft. Normally, they are assigned names which depict their primary functional employment. Thus, the master armament bus furnishes power to all armament components. The main bus furnishes power to all the various components of the aircraft itself. There will usually be secondary buses branching from their respective primary buses which aid in the distribution of power throughout the aircraft.

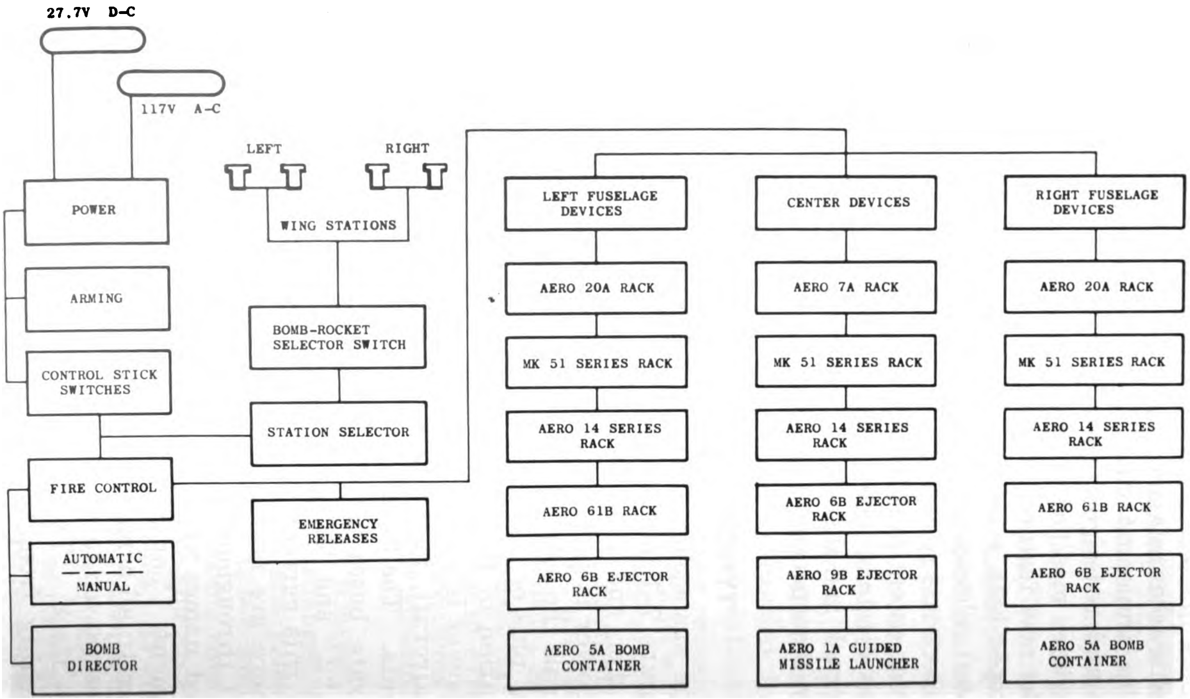


Figure 7–1.—Schematic block diagram of typical fighter aircraft armament system.

Mention is made of "essential buses" in publications. This is another name for "primary" buses. These are the ones which are designated to serve the flight controls, instrument lighting, fuel system lighting items, and other items that are necessary to the operation and control of the aircraft from an inflight standpoint. The various manufacturers use differing names for the same components and elements of armament at times. Therefore, it is necessary to recheck the nomenclature when any doubt exists as to the exact function of the device or component concerned. The present tendency is to use the words "primary" and "secondary" instead of "essential" and "main," respectively, when referring to the aircraft buses. Confusion should be prevented as to the exact bus referred to when this nomenclature becomes standard practice.

In at least one fighter aircraft, there are no secondary buses (d-c) at all. Secondary bus relays are used instead. Power from the main bus is fed directly to the various components of the aircraft. Ganged secondary bus relays, into which all components are wired, serve as secondary buses. In the event of electrical shorts and overloads in any of the components, the relays will open offering protection to these components of the aircraft.

In the modern fighter aircraft, the control stick grip contains several different switches. The ones of immediate concern here are the rocket firing switch and the bomb release switch. When these switches controlling separate circuits are closed, they actuate relays which in turn cause the bombs to be released and/or the rockets to be launched. When releasing bombs, the bomb/rocket selector switch is set to the proper position for the store concerned, and the station selector switch is set to afford the desired grouping of the stores to be released. The arming switch is set to either TAIL or NOSE & TAIL to give the type of arming needed for the bombs to be dropped. The stores are then released by actuation of the proper control stick switch. If rockets are to be launched, the arming switch has to be set to SAFE, TAIL, or NOSE & TAIL in accordance with the fuzing of the rockets carried.

If the fire control components are being used for bombing and launching rockets, the method selector switch is set to either MANUAL or AUTOMATIC at the pilot's discretion. The bomb director is either energized or left OFF as the circumstances warrant. Emergency release of the center stores may be effected electrically or manually in accordance with the particular type of racks fitted to the aircraft. Provisions are made for both means of release. The emergency electrical release switch or manual release is used for this purpose. It will be noted that the wing racks of the fighter aircraft may only be released electrically as there are no manual release provisions incorporated.

No one particular fighter aircraft will ever be fitted with all of the different types of fuselage suspension devices shown in figure 7–1. However, since this is a typical fighter aircraft, many types of devices capable of being employed on this aircraft are shown. From these racks and launchers may be suspended a variety of armament stores, such as guided missiles, bombs, special weapons, bomb containers, navigational packs, etc. The particular configuration to be employed is dictated by the type and mission of the aircraft concerned.

The wing station racks and launchers may also suspend a great variety of stores, such as 5-inch HVAR's, SCAR's, ASW rockets, general-purpose bombs up to and including 500-pound items, fragmentation bombs, water/sand filled practice bombs, rocket packages of 6- and 19-rocket capacity types, etc. Here again, the configuration will be determined by the type and mission of the particular fighter.

As an example of the switching arrangement for firing rockets, the following is the usual procedure. The sequence may easily vary with different aircraft and more especially with differing configurations of devices. Basically, the following will serve as an average examle. Selection of the type and amount of armament hould first be determined. In this case the ROCKET/BOMB SELECTOR SWITCH will be set on ROCKETS by movng the selector knob from SAFE to ROCKETS. In he fighter aircraft, the STATION SELECTOR is connected o the wing racks (outboard) through the bomb/rocket elector switch and is not used with the fuselage (cener) racks in this arrangement.

Next, the ROCKET PACKAGE SWITCH may be set on either 6-SHOT or 19-SHOT in accordance with the type of package loaded—if the package is used. The METHOD SELECTOR SWITCH is set to either AUTOMATIC or MANUAL. The AUTOMATIC setting connects the rocket iring circuit into the radar system to fire rockets at the roper instant during radar tracking. The MANUAL position allows the pilot to fire the rockets when desired. The rocket/bomb ARMING SWITCH has three positions: SAFE, TAIL, and NOSE & TAIL. Some rockets have nose fuzing, some tail fuzing, and still others have heads without fuzing. Those having nose fuzing, with armng wire installed, require that the switch be set to the NOSE & TAIL position. Likewise, those with base fuzng require the switch to be set at NOSE & TAIL. Those rockets having no fuzing may be fired with the selector switch in any of the above three positions. The TAIL setting of the switch is used when dropping bombs only.

When the MASTER ARMAMENT SWITCH is turned on to the ON position, the rocket firing system is readied for action. Power is also furnished to all of the armament circuits of the aircraft. A recheck should be made at this time, however, to insure that none of the other armament circuits have been energized by turning on the master armament switch if rockets ONLY are to be aunched. Only the rocket firing circuits should be energized at this time. When the rocket firing switch on the CONTROL STICK GRIP is depressed, the rockets should aunch instantly and in the sequence and quantity previously set up by the selector switch. Power is furnished to the rocket latch solenoid and to the rocket firing igniter at the same instant. As a result, the latch is retracted at the same time the rocket is fired, thereby affording the rocket an unrestrained flight from the launcher. Should the solenoid fail to work, a shear pin in the mechanism fails as the rocket motor creates a certain thrust and the rocket is launched by shearing this pin.

When rocket packages are carried and their enclosed rockets fail to fire, the entire package may be jettisoned in an emergency by actuation of the EMERGENCY SWITCH (electrical). However, individually suspended rockets, such as the 5-inch type and others in this category, may NOT be jettisoned from the outboard racks as no provisions are made for such a release. The rocket package uses the lugs of the combination rack and launcher for suspension and the single rockets are fitted into the launcher fittings. Thus, the package may be dropped the same as a bomb, but the single rockets may not be dropped if they fail to fire.

A pigtail which connects the rocket to the aircraft rocket firing circuit is secured to the receptacle of the rocket and, when the rocket has been fitted to the launcher, the pigtail is attached to the receptacle under the aircraft's wing. The pigtail of the rocket package is connected in a like manner to the underside of the wing. This pigtail is secured to the trailing edge of the combination rack pylon by two clamps. When the rockets are fired and the package jettisoned, the pigtail will break at its weakest point as the package separates from the aircraft. In some fighter aircraft, certain portions of the rocket firing circuit and portions of the gun-firing circuit are common to one another. However, both circuits are actuated by separate switches, relays, and releases.

In dropping bombs from the fighter aircraft it is necessary to position the bomb/rocket selector switch to BOMBS. The station selector is positioned so that the wing racks will drop singly or in pairs and the fuselage racks will release the left, center, or right store. Racks

the fuselage intended for special weapons will have
eir own separate monitoring and releasing circuits
nd controls. Normally, the special weapons rack cir-
it will be connected to the fire control system of the
ircraft so that full advantage of the automatic fea-
res of the radar system may be employed.

Several of the fuselage racks in current use are EJEC-
R TYPES. These racks forcefully separate the stores
om the aircraft at the instant of release. These racks
ill successfully eject the stores regardless of the atti-
de of the aircraft. A cartridge is electrically fired
to a chamber containing a piston. This piston, during
s linear travel, unlocks the sear, releases the carrying
gs, and imparts a sharp expelling force to the store.

The method selector switch is set to either MANUAL
r AUTOMATIC to match the type of drop to be made.
hen set to AUTOMATIC, the bomb releasing will be
ccomplished by the fire control system; and when set
MANUAL, the pilot has control of releasing the
ores. If the fire control system of the aircraft is used
r bombing, it has to be warmed up prior to use and
e necessary switches closed to couple this system to
e bombing circuits. The bomb director of the fire
ntrol system releases the stores when it receives elec-
rical impulses from the sight and radar networks.

The master armament switch is turned to the ON po-
ition to ready the combined circuits for bombing. If a
anual release is to be made, the pilot depresses the
ombing switch on the control stick grip at the proper
stant. If the bombing attack is made using the auto-
atic fire control features, the pilot is notified when to
epress the control stick switch by indicator lights as in
ver-the-shoulder and other types of tactical maneuvers.

TYPICAL ATTACK AIRCRAFT SYSTEM

Attack aircraft of the Navy may have the shape and
ppearance of fighter aircraft, or may be large enough
o be easily mistaken for patrol aircraft. Regardless of

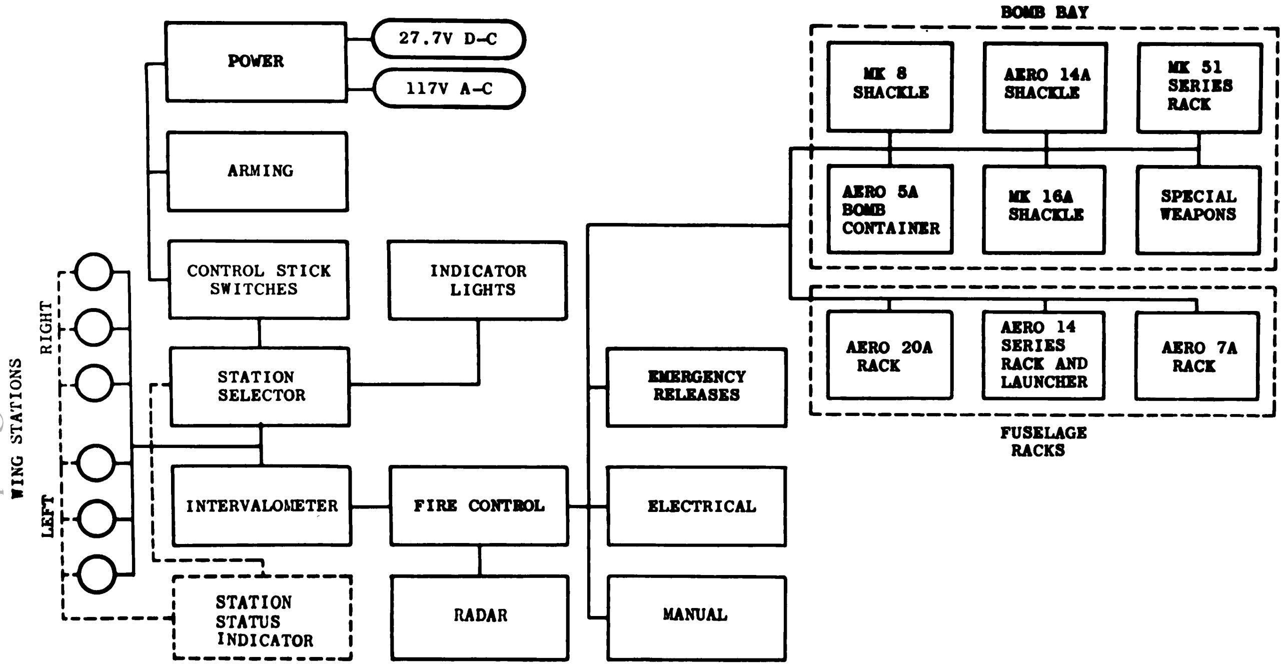


Figure 7-2.—Schematic block diagram of typical attack aircraft armament system.

ts shape and size, it has been specially adapted to its mission of attack in being provided with complete fire ontrol systems, provisions for all types of bombing, ocketry, and launching of guided missiles and special weapons. No one attack aircraft is provided with all f the above features, but attack aircraft in general are o provided. Some have bomb bays, others do not. Some have several wing racks, others do not. Some have uselage racks and others do not.

It will be noted in figure 7–2 that the typical attack aircraft has, as does the fighter, two separate sources of power for the operation of its various components. A primary d-c bus supplying 27.7 volts affords the power necessary to operate the controlling features of the airraft. The primary a-c bus supplies all the power necesary to operate the radar and other components requiring 17 volts, such as electrically primed ammunition guns, ertain instruments, and heaters.

The d-c power supplied to the attack aircraft is derived from either a d-c generator or battery, or both. The a-c power is normally derived from one or more a-c generators. In the larger attack aircraft, there may be more than one of each type of generator. The a-c voltage is 3-phase, 400-800 cycle regulated to 117 volts, plus or minus 5 volts. The d-c power is also regulated to 27.7 volts, plus or minus 0.5 volt. Still another method of deriving 117-volt, a-c power is through the use of nverters. In this type installation it is not necessary to have both a d-c and an a-c generator. The inverter takes the d-c power at 27.7 volts and converts it into 117-volt, a-c power. In this system the inverter takes the place of the a-c generator.

The control stick switches, shown next in line, are used among other things for dropping bombs and launchng rockets. Impulses to release the stores are routed to the suspension devices when these switches are closed. The station selector is set up for the desired grouping and types of armament to be used and the INTERVALOMETER is set to give the desired spacing when bombs and rockets are to be used. In the event that a STATION STATUS INDICATOR circuit is incorporated (shown as a broken line circuit in figure 7–2), it is tied in with the station selector and shows, through indicator lights on the pilot's or bombardier's console, exactly which stations have stores loaded.

The fire control system with its incorporated radar, when in use, sends its impulses to the intervalometer. As the fire control problem is solved by the fire control system, the stores will be released at the exact instant for maximum effectiveness. The stores suspended may be either within the bomb bay as in some types of attack aircraft, or on the fuselage racks as in others.

The bomb bay and fuselage racks may be cleared of stores in an emergency either electrically or manually through actuation of the EMERGENCY RELEASE DEVICE. However, the outer wing racks may only be cleared of stores through actuation of the electrical release, or releases. The most widely employed suspension device used in the bomb bay is the BOMB SHACKLE. It is not rigidly attached to the aircraft. It is suspended on lugs or shackle hooks so that it may be free to move laterally about its suspension points on the guide rails of the bomb bay. Shackles are also used in the overhead of the bomb bay in some instances in pairs to suspend heavy stores. They are self-aligning to the store due to the fact that they are not rigidly secured to the aircraft, but are free to make lateral movements around their shackle hooks.

There are other types of racks used in the attack aircraft bomb bays, as will be noted by reference to figure 7–2. Even practice bomb containers may be suspended within the bomb bays. Special weapons carried in the bomb bay have their own specialized type of suspension. The bomb bay may be cleared and an adaptor used, or a special installation may be adopted for the store and aircraft. The intervalometer is set to either TRAIN or SELECTIVE so that the stores within he bomb bay or under the fuselage, depending on the particular aircraft, may be dropped in a timed sequence or selectively at the desire of the pilot or bombardier. The bomb bays of the attack aircraft have service lights placed at strategic locations to enable operators to load tores and perform other work within. The sequence of vents in releasing stores from the bomb bay are set so hat the bomb bay doors have to be opened to a predetermined position before the stores may drop. The doors open first, the stores are dropped, and the doors close again after a 3-second delay. All of these actions occur automatically when the emergency switch is actuated. In an emergency the pilot may not have time to perform all of these actions. Thus, he closes the emergency switch and may, more or less, forget about the jettisoning of his stores, as the release is performed automatically as described.

Provisions are made in certain attack aircraft for suspension of JATO EQUIPMENT. Suspension points and attachments are provided at the best aerodynamic locations about the aircraft and the necessary firing and jettisoning circuits made available at these points ready to receive the connectors from the JATO bottles. Elaborate precautions in the form of safety switches in the JATO circuits prevent these power boosting units from being fired accidentally.

Due to the great variance in sizes of the attack type aircraft as a class, great diversity may be expected as to the overall capabilities of this aircraft class. It is a generally known fact nowadays that the smallest of operational aircraft of the Navy may load, carry, and release special weapons. Therefore, the smallest of the attack aircraft may take part in this highly specialized type of warfare. Naturally, the larger types of attack aircraft are likewise equipped and may handle a greater load and/or larger special weapons. The larger attack type aircraft may also be fitted with bomb bay adapters which enable them to become aerial tankers, bombers, photographic planes, or freighters, and to assume many other configurations as specific needs arise. The larger jet type attack aircraft, in spite of their weight, size, and speed are still capable of taking off from and landing aboard aircraft carriers. This fact naturally enhances their usefulness as weapons, as they may operate from land bases or from far at sea. The types and amounts of armament carried may be altered with minimum loss of time to correspond with the tactical situation at hand. Usually, all types of attack aircraft are capable of defending themselves with the defensive armament carried and may even seek to engage the enemy on occasions. However, the larger types of attack aircraft are provided with tail turrets for defensive purposes only.

TYPICAL PATROL AND ASW AIRCRAFT SYSTEMS

The patrol type aircraft are the largest of the three classes discussed in this chapter. They have tremendous range and are capable of delivering large quantities of conventional armament stores as well as various classes of special weapons. The ASW type aircraft may range in size and type from the ASW helicopter to the ASW twin-engined bomber. However, there is one type especially designed and constructed to perform ASW work entirely. Whereas previously a "hunter-killer" team consisting of two aircraft working in close coordination in tracking down and destroying enemy submarines was employed, the same is currently performed by a single aircraft. This specialized aircraft tracks down, pinpoints, and destroys the submarine. The helicopter and the twin-engined bomber have been modified by installation of the latest detection gear and necessary changes to airframes to enable them to perform ASW work.

As in the other types of aircraft previously mentioned, the ASW and patrol aircraft derive power to operate their armament components from generators, batteries, and inverters. (See fig. 7–3.) In a number of the larger aircraft, switches duplicating those on the control

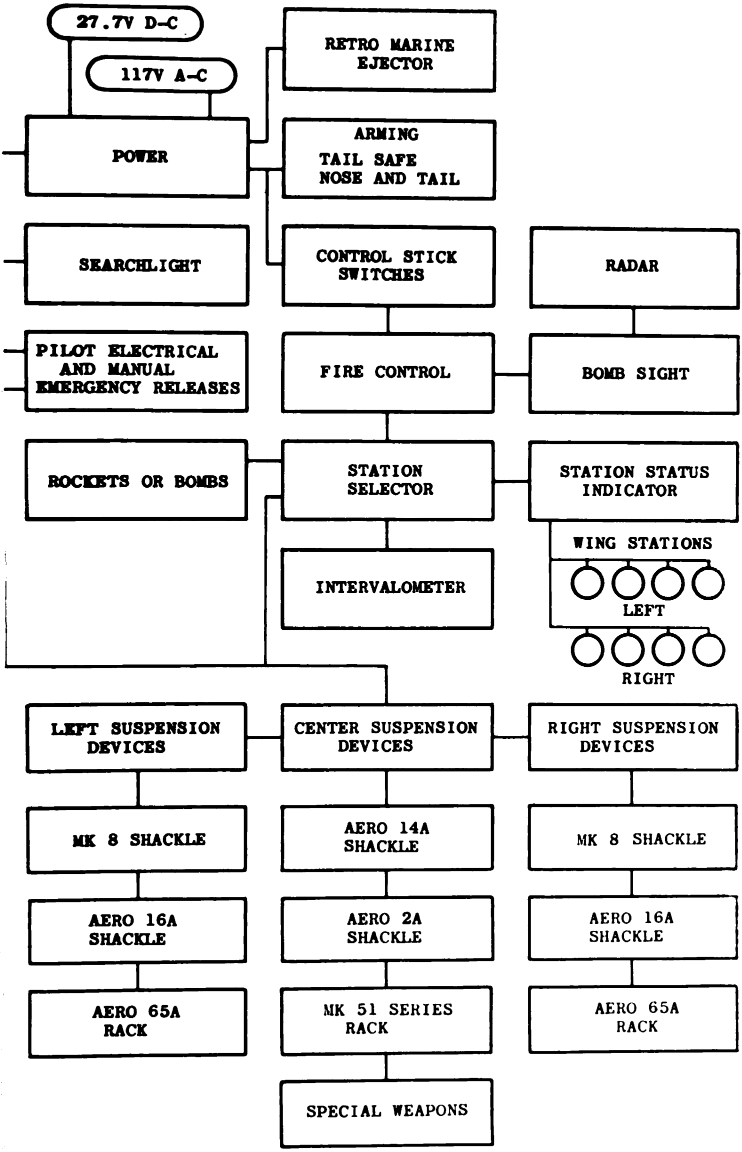


Figure 7—3.—Schematic block diagram of typical patrol and ASW aircraft armament systems.

stick or control wheel may be located in the navigator's compartment, the bombardier's compartment, or elsewhere.

Between the power supply and the racks themselves is the emergency switch for releasing the stores quickly. Several circuits are involved in making an electrical emergency release of all stores. However, it is imperative that this operation be made as simple as possible for the pilot as he will have many other phases of flight control and survival to attend to in such an instance. Therefore, all the circuits involved are usually connected to one switch and the actuation of this switch will automatically accomplish all of the actions incident to getting rid of all stores in a hurry. In some of the larger aircraft the armament circuits as a rule are not so closely interconnected as in the fighter aircraft. There will be more stations throughout the larger aircraft from which the armament may be operated. However, the pilot will still have control of all armament circuits through the use of special armament switches within easy reach. In this way he is able to release the stores carried in the event of an emergency and have control over the other stations remote from him.

Manual emergency releasing is accomplished by means of a MANUAL EMERGENCY RELEASE DEVICE. This device consists of a manual release handle with its associated arms, bell cranks, sheaves, wires, turnbuckles, etc., and is usually actuated by being pulled out to its fullest extent to effect release of the stores. In some of these devices two positions of the handle are employed. Pulling the handle out to the first position may connect certain electrical circuits of the armament system and open bomb bay doors. It may even set up the bomb stores and rockets for electrical release. The second position will release all bomb stores at once. There are many safety devices incorporated in the electrical circuits, such as those to prevent bombs from being dropped prior to the bomb bay doors becoming fully opened and locked, those to prevent accidental dropping of bombs and launching of rockets, and others. In some instances, the emergency manual release is interconnected with the bomb bay emergency release system so that when the pilot pulls the emergency release handle, the bomb bay doors are automatically opened by their emergency hydraulic operating system, the stores are released, and the bomb bay door closed, all in rapid sequence.

In most of the patrol and ASW type aircraft there is installed a MARINE MARKER PNEUMATIC RETRO-EJECTOR. Power to drive the COMPRESSOR for this device is derived from the aircraft's power supply (27.7-volt, d-c), and the compressed air is stored in a flask which, in some installations, is also used to operate the sonobuoy dispenser. The marine markers are ejected 180 degrees from the direction of flight at a linear speed equal to that of the aircraft groundspeed at the time of release.

When either the bomb or the rocket launching switches on the control stick grip are depressed, impulses are sent from there through the armament system. The fire control system, being a component of the armament system, receives these impulses either indirectly through the gunsight, or directly through the circuits connected to the radar components of the fire control system. There are many different types of fire control systems used in patrol and ASW aircraft. These classes of aircraft will have more than one system installed in each. There will be one system for dropping bombs, another for launching rockets, and still another for the turrets, or a combination of one or more fire control systems may serve one or more of the armament components.

Arming devices for racks and shackles may be actuated by either manual or electrical means. Originally, arming was performed manually only. The device for arming was a lever or pull handle in the cockpit connected to the arming lever of the rack or shackle by flexible cable. Presently, however, arming is performed by electrical means through electrical solenoids. The pilot, or bombardier, has only to close a switch to arm the store. Although manual arming provisions are still incorporated in several of the racks and shackles presently in use, these devices are normally armed by electrical arming devices, fitted either as an attachment or incorporated as an element of the device. The ARMING DEVICE may be adjusted so that the spring tension holding the arming wire in the arming device latch will be just enough to retain the arming wire against wind resistance and vibration, but not so tightly that the arming wire fails to pull out of the device if and when the store is dropped SAFE.

The impulses received by the suspension, arming, and releasing devices of the aircraft inevitably pass through some form of fire control contained within the aircraft. Early fire control sometimes took the form of sticking a wad of chewing gum on the windshield at a convenient location as a marker with which to aim the guns, or along the fuselage as a reference point for dive bombing runs. The illuminated optical sight supplanted the ring and telescope sights which had replaced the chewing gum, and later on these optical sights were connected into the radar circuits. The optical sight became lead computing prior to its association with radar. Therefore, when radar did emerge, there was an excellent type of sighting system ready for connection into the radar circuits. Thus, fire control as we know it today had its inception.

The fire control systems of today range from the earlier ones, which received certain information from the radar that was then fed to the system manually by the operator, to the more recent ones, which practically eliminate the need for an operator. It is common knowledge today that after an aircraft has been maneuvered into the combat area after takeoff by the pilot, the RADAR FIRE CONTROL SYSTEM will select an enemy target, which is within range of the armament employed, lock on to this target, track the target while flying the aircraft, and when at the proper range will fire the guns, launch the rockets, or drop the stores carried in accordance with how it has been armed. There are so many different types of fire control systems in current use, and so many new types on the drawing boards, under construction, and actually in the test stages that there is little use discussing any one system in this chapter.

Station selectors are designed to allow sequential or selective release of armament stores. There are many modifications of this device. The selector is adaptable to any type of aircraft through replacement of the dial faces to match the loaded stores and/or rockets. The station selector contains an AUTOMATIC STEPPING SELECTOR SWITCH which affords the sequential or selective release of wing station shackles and racks and/or firing of rockets.

The intervalometers used in the patrol and ASW aircraft are the same as those used for other types of aircraft. As employed in the patrol and ASW aircraft, the intervalometers are interconnected with the wing racks, the racks in the bays of the wing and/or fuselage, and the station selector. They provide either train or selective releasing of the stores. The TRAIN setting of this instrument is adjustable so that timed intervals between impulses may be varied to desired fractional parts of a second.

The STATION STATUS INDICATOR gives visual signals concerning the number of bomb stores loaded on the wings and in the bays, as well as the number of rockets loaded on the wings. Many of the components of the modern aircraft contain telltale lights, or status lights, which show the condition of various elements of armament and devices. Among these are lights placed on sonobuoy systems, marker systems, the master armament switch, fire control circuits, on torpedo and mine control panels, etc. The station status indicator circuit is tied into each of the items it monitors; and when stores, rockets, and other items are loaded, lights will be energized on a panel. When these items are released or fired, the lights will go out, indicating that the items are no longer attached. A quick glance at the panel shows just how many items are left and where they are located.

In certain of the patrol type aircraft the armament master switch, which normally has control over all armament in other types, has no influence over such armament equipment as sonobuoy gear, photographic gear, searchlight gear, and the firing of guns. It will also be found that the rocket firing circuits and the stores releasing circuits of the patrol type aircraft are entirely separate from one another.

As in all types of aircraft, there is a specified sequence of releasing stores and firing rockets. The patrol and ASW aircraft are not exceptions. A specified sequence is necessary in order to assure the minimum imbalance of the aircraft itself after partially releasing the stores and rockets. If all stores and rockets were suddenly dropped and fired from one wing alone, a yawing of the aircraft could easily result due to the reduced wind resistance about that particular wing. There would also be a lateral imbalance set up as the weight of the stores and rockets on one wing became zero. There are also certain limitations as to the gross weight of stores and rockets which may be carried under each wing. This limitation is determined by the engineers who design the particular aircraft concerned. The gross weight of stores and other gear carried within the bomb bay is similarly limited. Of course, the capability of the aircraft to lift, carry, and land with total loads over and above the weight of the aircraft itself is determined by the aerodynamic characteristics as well as the structural strength of the aircraft, plus a substantial safety margin.

It is impractical to beach an aircraft each time it is necessary to replenish the armament. In order to rearm the waterborne type of patrol aircraft it is expedient to have some type of boat which can transport the stores, rockets, and other armament to the aircraft. A relatively inexpensive type of boat, the rearming boat, has been assigned to this duty. The wing racks are loaded directly from this boat. Also, the types of aircraft having wing bays for stores are loaded from the rearming boats.

INFLIGHT REFUELING has been given a great impetus by the advent of the relatively short-ranged jet fighter aircraft. In order to keep them airborne for protracted periods, it is necessary to refuel them in the air. Several different systems have been tested to find one, or more, that would prove practicable for this work. The drogue and probe system apparently has gained much favor over other systems. Essentially, this system is comprised of large tanks with connected hoses which may be reeled in and out. In some installations, the tanks are suspended from racks and/or shackles within the bomb bays. In others, the tanks, reels, and other components are assembled on an adapter which is lifted into the bomb bay and connected to suspension devices there. One of the latest installations has been made in a large patrol aircraft which contains four house and reel assemblies. Four fighters may be simultaneously refueled. Certain of the VA type aircraft also are configured to act as tankers.

BOMB RACKS AND SHACKLES have shown great improvement as to weight carrying capabilities in the last few years. Highly specialized racks and shackles have been developed for carrying special weapons. However, some of these same suspension devices will also carry conventional stores and guided missiles. It is advantageous to have devices which will, in addition to their specialized use, carry other types of stores. This maintains a high degree of flexibility in their employment. Shackles may have either single or double hooks for suspending purposes. Bomb racks may have two-, three-, or four-hook suspension. Both shackles and racks may have either 14- or 30-inch separation between suspension points.

EJECTOR RACKS and SHACKLES are in use on fighter, attack, patrol, and ASW aircraft currently. It was found that under certain conditions, the stores needed a downward thrust on their after ends so that they would separate from the suspension devices cleanly. The ejector was the solution to this problem. A shell, electrically fired within a chamber, forces the contained piston downward, giving a forcible push to the store aft of its center of gravity. These ejector racks and shackles require more maintenance and closer inspection than do the conventional types. Care has to be exercised in the stowing, transporting, and insertion of the propelling charges, or shells. These shells are classed as pyrotechnics (fire hazard only) and have to be handled in accordance with existing instruction on this class of material.

SWAY BRACES for racks are made adaptable to any store that the rack is capable of suspending. The adjustable features of the sway braces, which are integral with the racks, serve as a means of eliminating sway of the stores loaded on the racks concerned. Sway braces used in conjunction with shackles are not part of the shackle, but are attached to structures, beams, girders, and other members specially placed within the bays.

Modifications to racks and shackles are made for the purpose of producing a better device in one respect or another, or to adapt them to certain new uses. Practically all racks and shackles have been modified several times before their useful life ends. Different modification numbers are assigned also to distinguish between right- and left-hand items.

QUIZ

1. Stores mounted on the wing racks of fighter aircraft may be released
    a. electrically only
    b. manually only
    c. electrically or manually
    d. by any of the above

2. When firing rockets having base fuzes, the arming switch is positioned at
    a. SAFE
    b. TAIL
    c. NOSE & TAIL
    d. none of the above

3. The most widely used suspension device in a bomb bay is a
    a. rack
    b. launcher
    c. shackle
    d. ejector

4. In aircraft having bomb bays, emergency release is
    a. manual
    b. electric
    c. automatic
    d. semiautomatic

5. The station selector used in most types of aircraft is
    a. a relay
    b. an automatic stepping switch
    c. a circuit breaker
    d. none of the above

6. Intervalometers are used to provide electrical impulses directly to
    a. the racks to be released
    b. the station selectors for distribution
    c. the stores mounted on the racks
    d. all of the above

7. Sway braces used with shackles are
    a. attached to the aircraft structure
    b. attached to the shackle
    c. constructed integral with the shackle
    d. none of the above

8. Bomb racks may have how many suspension points?
    a. Two
    b. Three
    c. Four
    d. All of the above

9. In one type patrol aircraft, the master armament switch controls the
    a. sonobuoy gear
    b. searchlight gear
    c. firing of the guns
    d. none of the above

10. The rocket package pigtail is secured to the combination rac and launcher by
    a. safety clips
    b. two clamps
    c. Fahnestock clips
    d. alligator clips

11. The aircraft a-c power supply is
    a. 117-volt, 400-800 cycle, single-phase
    b. 117-volt, 60-cycle, two-phase
    c. 117-volt, 400-800 cycle, three-phase
    d. 117-volt, 32-cycle

12. The inverter is supplied with
    a. 117 volts d.c.
    b. 12 volts d.c.
    c. 27.7 volts d.c.
    d. 6 volts d.c.

13. The station status indicator shows
    a. the number of stores loaded
    b. the type of stores loaded
    c. whether the stores are fuzed or not
    d. stores have been released by lighting up

14. Timed sequence drops require the intervalometer to be set
    a. SELECTIVE
    b. AUTOMATIC
    c. TRAIN
    d. BOMB

15. The 5-inch rockets are released in an emergency by the
    a. selector switch
    b. emergency switch
    c. intervalometer
    d. none of the above

CHAPTER 8

BOMBING EQUIPMENT

THEORY OF BOMBING

All of the units of equipment used in bombing from
e air have been originated, planned, designed, con-
ructed, and placed into service for the purpose of
livering to an enemy the maximum amount of destruc-
ve armament with the greatest possible accuracy,
nder the most practicable type of attack consistent
ith the prevailing tactical situation and to perform
rtain defensive functions. The situation will deter-
ine whether high altitude, low altitude, glide, dive,
ss, or other types of bombing will be used during an
gagement.

There are many factors involved in the solution of the
mbing problem. Drift, range, trail, cross trail, wind
nditions, ballistic coefficients, and others have to be
ckoned with before the problem may be solved. The
athematical solution to the bombing problems will not
discussed in this chapter as it is not deemed neces-
ry. However, some of the more pertinent factors in-
lved in bombing will be discussed.

Vacuum Conditions

In order to fully appreciate the factors involved in
lculating the actual impact point of a bomb dropped
om altitude in air, it is helpful to consider the same
roblem from a theoretical standpoint in which the bomb
lls through a vacuum. There are formulas with which
calculate the speed of a falling body. They are ex-

pressed in the terms of the attraction of gravity and the length of time this attraction will act on the falling body. It can be proved that this falling body or object will accelerate at a constant rate. This rate is known as the ACCELERATION OF GRAVITY. Due to the fact that a bomb is always dropped from a moving aircraft, the motion imparted to it by the movement of the aircraft at time of release would remain constant in direction and magnitude in its flight through the vacuum. This means that, if the aircraft did not change course or speed, the bomb would remain vertically below the aircraft throughout its fall and the aircraft would be directly over the point of impact when the bomb hit. The trajectory followed by the bomb dropped in a vacuum from a moving aircraft would form a parabola. This parabolic path is called the VACUUM TRAJECTORY. Also, in a vacuum, the ground distance covered by the falling bomb from the point directly under the aircraft at the instant of release to the point of impact of the bomb is known as the VACUUM RANGE. (See fig. 8–1.) The vacuum range is equal to the SPEED OF CLOSING (which is equivalent to the relative speed and considers the range component of any target motion) times the time of fall of the bomb.

Actual bombing has to be performed through air instead of a vacuum. As a result, air resistance has important effects upon the bomb after release. Air pressure or resistance decreases the vertical velocity of the bomb at any given instant in its trajectory. This factor automatically increases the time of fall of the bomb. At the same time, the horizontal velocity imparted to the bomb by the moving aircraft diminishes due to the air resistance. This causes the bomb to lag behind the aircraft during its fall (if the aircraft maintains the same speed and direction after release) and to trail behind the vertical from the aircraft. Thus, when the bomb strikes the ground, the aircraft is some distance ahead of this point of impact. This distance is called TRAIL. The factors affecting the trajectory through air

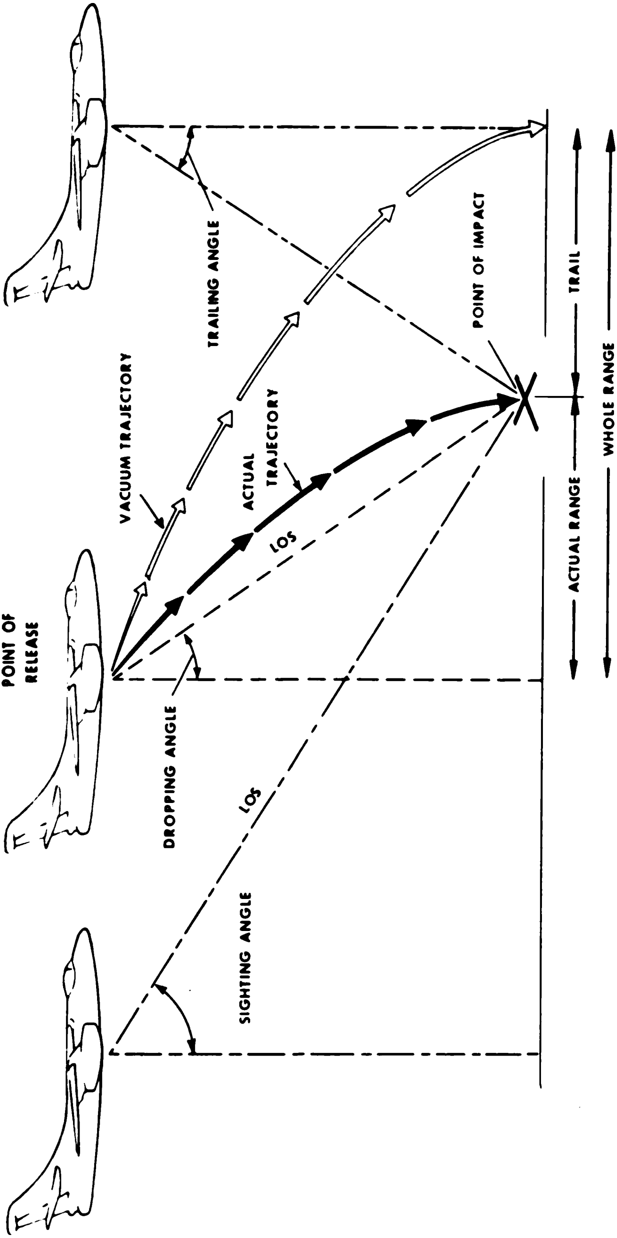


Figure 8-1.—Various phases of the bombing problem.

are the shape, weight, and skin friction of the bomb, the altitude at which released, and the airspeed at instant of release.

In explanation of the terms used in figure 8–1, it will be noted that:

The SIGHTING ANGLE is the angle between the line of sight (LOS) and the true vertical at any instant. This angle is normally determined by spin axis of the bombsight gyroscope.

The DROPPING ANGLE is the angle between the line of sight and the spin axis of the bombsight at the instant of release. At this particular instant, the sighting angle and the dropping angle are equal.

The TRAIL ANGLE is the angle between the spin axis of the gyroscope and the line of sight at the time of impact of the bomb, provided the aircraft maintains its speed and direction.

The ACTUAL RANGE is the horizontal distance the bomb travels between the instant of release and the instant of impact by the bomb.

TRAIL is the horizontal distance between the points of impact of an actual trajectory and a vacuum trajectory.

The WHOLE RANGE (vacuum range) is found to be equal to the actual range, plus the trail.

It will be found that trail is always astern of the aircraft. The amount of trail that exists is dependent upon the amount of air resistance. Air resistance is equivalent to the indicated airspeed of the aircraft at the time of release, and the length of time the air resistance acts on the bomb. Total air resistance is proportional to the altitude of release. Values for actual trail and time of fall do not have to be computed in solving the bombing problem. For each bomb type, and other droppable pieces of armament, the Bureau of Ordnance has determined these values precisely at the proving grounds.

Such a value is known as the BALLISTIC COEFFICIENT. This coefficient indicates the bomb's ability to penetrate air. Thus, the coefficient has an effect on trail. Upon setting the correct ballistic coefficient into the bombsight, corrections for trail are automatically made for the particular bomb, or store, being utilized.

Drift

Discussion of the bombing problem so far has been based on the conditions of dropping in still air or in a vacuum. It is almost as impossible to bomb in still air as it is in a vacuum, as the airmass at any location at any given time is practically sure to be in motion. If it were possible to invariably make bombing runs either up or down wind exactly, there would be little reason to take drift into consideration. Since this is also highly impractical, it follows that drift will have to be dealt with. Normally, the course made good over the ground is NOT that steered by the pilot. Wind direction causes this difference. The angle formed between the heading of the aircraft and the direction of movement of the aircraft over the earth's surface is known as the DRIFT ANGLE. It is obvious that, if the wind acts to set the aircraft off its course when blowing in a direction that is not parallel with the course steered, the same will happen to the bomb that is dropped from the aircraft.

Heading directly for the target will not solve the drift problem. In so doing, the path of the aircraft over the ground would be constantly changing until it eventually headed directly into the wind. This would take the aircraft over the target, but the bomb would never hit the target because drift had not been accounted for in this type of approach. The aircraft has to be headed in such a direction that the correct drift angle is established during the approach. Thus, the aircraft, instead of being headed directly for the target, will have its heading offset from the true ground course to the target by the amount of the drift being experienced. (See fig. 3–2). A lateral error is experienced under the above conditions. This error is called CROSS TRAIL. It is compensated for by the mechanisms of the bombsight so that the point of impact of the bomb will be on the target.

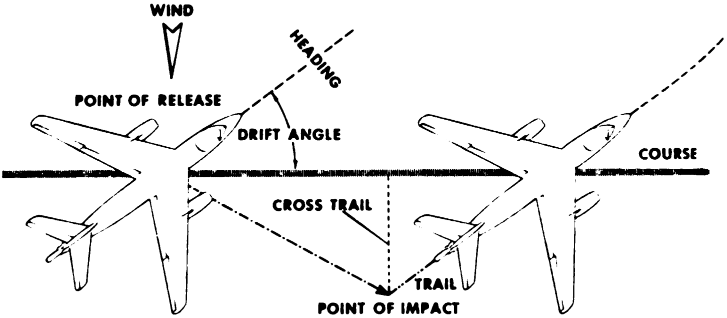


Figure 8—2.—Cross trail compensation.

If the target is in motion during the bombing run or approach, the same effect is generated in the bombing problem as would occur had a cross wind existed at that time. The bombsight solves target motion just as if it were cross wind. Quite often there will be both target motion and cross wind. These factors may be additive or subtractive. However, this fact has no effect on the ability of the bombsight to solve the problem. The bombsight solves the bombing problem through the employment of angles rather than distances. Therefore all information fed into the bombsight is in the form of angles, altitude being the only exception. The standard angular unit value is the MIL which is the angle subtended by an arc whose length is one-thousandth of the range.

TERMINAL VELOCITY of freely falling bodies is a complicated study in itself. However, it might be well to point out a few basic facts concerning this subject for purposes of general information. A freely falling body of whatever shape, size, weight, or substance is acted upon by the air through which it passes. The body may have a horizontal component in its motion imparted by the aircraft. Air resistance diminishes the velocity of this motion. Likewise, the vertical velocity component gained from the forces of gravity are diminished. Due to these facts, the object will, at some point in its fall reach a velocity at which the resistance of the air through which it is falling balances the effects of acceleration of gravity. It will accelerate no further. From this point until it reaches the ground, the body will be traveling at a constant velocity. In such a state, the body is said to have reached its terminal velocity. Two factors which determine the terminal velocity of a falling body are its shape (streamlined or roughly shaped) and weight. Shape is the dominant of the two. Dropped from an extremely high altitude, an aircraft mine may reach its terminal velocity prior to hitting the earth. A streamlined general-purpose bomb dropped from the same altitude probably would not reach its terminal velocity because its shape would require too much time in flight.

Terminal velocity is usually defined as a HYPOTHETICAL maximum speed a body may reach under certain prescribed conditions. These conditions involve straight flight or fall, given weight, an unlimited distance in which to accelerate in air of specified uniform density (usually standard sea level air density), and others. It may readily be seen that terminal velocity is a hypothetical speed, as it would be extremely difficult to reproduce conditions necessary to perform actual tests for terminal velocity on most bodies of reasonable weight and fineness. It is interesting to note, however, that it has been calculated that an average man of 200 pounds with parachute and other paraphernalia common to the dress of a service flyer may reach terminal velocity in a free fall (delayed opening jump) rather quickly. This speed will be in the neighborhood of 140 m.p.h. His weight is relatively small (due to lack of density of the human body as compared with other substances) and the resistance offered by his body and the gear worn is tremendous. Terminal velocity has been calculated for each class of droppable stores as well as other armament.

So far, mention has been made of horizontal bombing only. Later in this chapter, other types of bombing will be discussed. The principles of bombing discussed above are for horizontal bombing. However, they are basic for all types of bombing problems. Also, the above discussion assumed the use of a bombsight (visual type) which is used only in horizontal high and low altitude tactics.

INTRODUCTION OF RADAR TO BOMBING

Purpose

During World War II, bombsights with radar ranging were developed and have been used extensively since that time. The introduction of radar to bombing has brought about a great advantage in that bombing may be carried out in almost any type of weather and during darkness. It is no longer necessary to be able to see the target in order to get hits. There is also an offset feature incorporated into the bombing system which allows targets presenting an obscure image on the radar to be successfully bombed by reference to nearby clearly defined objects. Thus, the purpose of introducing radar to the bombing circuits of the aircraft was to enable the bombardier to make successful attacks in spite of his inability to visually see the target.

Incorporation

Radar was not incorporated into the bombing circuits of the aircraft without difficulty. The first attempts revealed the fact that the radar did not present displays with sufficient information for radar bombing. It was found that the targets could be located without too much difficulty and that there was sufficient accuracy in azimuth. However, it lacked accuracy in ranging and tracking. A system which accurately gave information on these latter factors was desperately needed for successful radar bombing. Such a system was developed to meet the needs. Its original designed employment was for low altitude bombing of surface vessels, but it was found that it could be equally effective against any target visible to the radar.

Continued research and development in the field of radar bombing has produced many new pieces of equipment capable of increased accuracy, dependability, and effectiveness. Naturally, this new gear is not limited to any one class aircraft in its use. Different systems have been adapted to use in all types of naval aircraft. Currently, all types of aircraft may engage in radar bombing, being restricted only to the tactical employment best adapted to the particular aircraft type.

The various radar bombing systems have been incorporated into the armament circuits of the aircraft in such a manner that they effectively release the stores at the proper instant. They track the target, establish the closing rate between the aircraft and the target, and compute other information for solution of the bombing problem. About the only information manually fed this radar bombing system is altitude and the ballistic coefficients of the stores carried. The computer takes this information and other data generated by the system and effectively solves the bombing problem.

Aircraft armament circuits were not drastically changed to accommodate the radar elements to form the radar bombing systems. After space was found for containing antennae and other components, interconnecting the radar with the armament was relatively simple. Radar bombing systems often contain elements which also make it possible to fire rockets automatically.

Results

Integration of radar with the normal bombing system of an aircraft provided a means of establishing the CLOSING RATE between the aircraft and the surface target. Radar performs this task by furnishing a RANGE MARK for tracking the target echoes on the RADAR INDICATOR. The information obtained from the tracking process, when added to the altitude and ballistic information, are fed into the COMPUTING CIRCUITS where the total information is used to compute the RELEASE RANGE and automatically release the stores at the proper in-

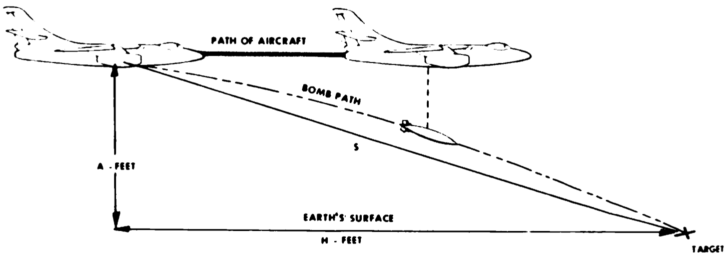


Figure 8—3.—Distance and slant range of released store.

stant. As previously mentioned, the altitude and ballistic information is set in manually by the operator.

The function of the integrated radar bombing system is to determine exactly the proper distance from the target at which to release the stores to afford a direct hit. This distance concerns two factors — FORWARD VELOCITY of the stores at instant of release and the TIME OF FLIGHT. (See fig. 8–3.) The forward velocity is equal to the actual groundspeed of the aircraft at time of release. The time of flight is equal to the time of fall of the stores and is dependent upon altitude, gravity, and the ballistic factors. Since the factors of gravity, altitude, and ballistic coefficients are known or measured, groundspeed is the only unknown in the bombing problem. Thus, groundspeed, or the closing rate, of the aircraft with respect to the target must be solved.

The search radar of the system determines the SLANT RANGE from the aircraft to the target. When tracking is provided by following the target echo, as this indication moves down the radar indicator screen, the SLANT RANGE CLOSING RATE for any instant is established. This closing rate decreases from point to point as the aircraft nears the target even though its ground velocity remains constant. Due to this fact, it is necessary to convert the slant range into horizontal range to determine the HORIZONTAL CLOSING RATE. However, if the bombing run is made at low altitude, the closing rate determined from the slant range may be taken as the horizontal closing rate with only a slight error until the time when the aircraft is close to the target. For this reason, tracking action is stopped when the target comes within a predetermined range. This range is dependent upon the altitude of the bombing run.

BOMB DIRECTORS

Low Altitude Bombing Director

With the advent of the tactical type of nuclear weapon, a definite need arose for safe and effectual methods of delivering these weapons by aircraft. It was found that loft bombing methods offered the best solution to this problem. Properly executed with the right type of bombing device, this loft bombing system permitted the pilot of a fast aircraft to successfully drop on the target and to escape. The equipment used as a director is familiarly known as low altitude bombing system (LABS). This system may be used for either loft bombing or over-the-shoulder techniques of bombing.

The loft bombing attack requires certain information to be computed in advance of the actual attack. Airspeed and altitude must be determined, a suitable landmark near the target selected, and tables consulted to select the proper aircraft and stores characteristics, before the aircraft is airborne. From the tables is determined the proper BOMB RELEASE ANGLE which is the angle at which the particular type of bomb should be released. Also the time in flight (run-in) between the landmark and the pull-up must be calculated. All of this information plus compensations for wind at the target are set into the LABS gear. As the pilot nears the target at low altitude, he is guided in his flying by instruments which indicate roll, pitch, and yaw. In order to fly the proper approach he keeps these instruments "centered" or "zeroed" to insure that he is flying straight and level so that the stores will be dropped on the target.

After a preset time the gear will indicate to the pilot when to begin the pull-up. He previously depressed and held depressed a switch directly over the landmark to start the timer. During the pull-up, the pilot will be guided by the instruments which indicate yaw and accelerations of gravity. He prevents yaw and holds accelerations at the predetermined figure until the indicator light goes out, at which time the pitch angle is reached and the store is released. From this point on the pilot is free to take the best retiring measures possible.

The TIMER is mounted in the cockpit of the aircraft within reach of the pilot. (See fig. 8–4.) It controls the interval of time between depressing of the switch and the beginning of the pull-up maneuver by the pilot. At the end of the time preset by the pilot, the timer causes an indicator light to be energized. The RELAY BOX contains relays, fuzes, bridge circuits, and potentiometers It receives the signals from the timer and the angle selector switch and translates these data into proper signals which give the desired mode of operation. The VERTICAL GYROSCOPE establishes a vertical reference for the system and determines the point at which the aircraft reaches the preset store release angle. It is mounted in universal gimbals so that it is free to move unrestrictedly in pitch (movement around the lateral axis of the aircraft) without tumbling. The gyroscope, through indicating devices on its roll and pitch axes, sends information to the pilot's instruments.

As previously mentioned, the correct store release angle is set before flight. There are two switches on the pitch axis of the gyroscope. These switches are set by dials, and one may be set for loft bombing and the other for over-the-shoulder bombing. The pilot selects and sets the proper switch for the mission concerned. The switch he uses for a particular mission is deter-

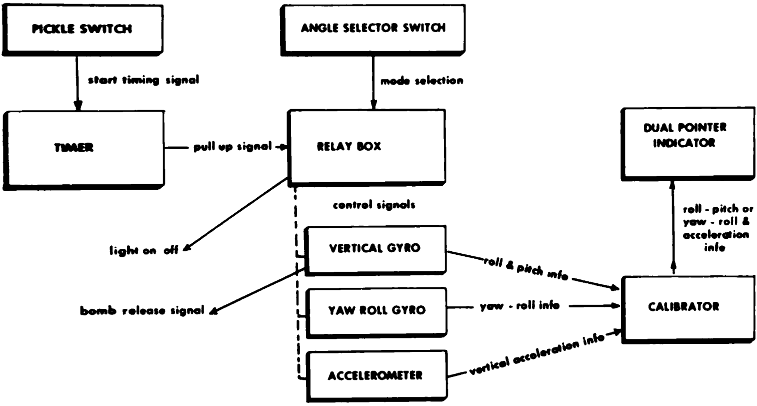


Figure 8—4.—Schematic of low altitude bombing system.

mined by the angle selector switch by way of the relay box.

The YAW-ROLL GYROSCOPE is mounted in the aircraft with its axis parallel to the lateral axis (the axis through the length of the wings) so that it may sense yaw and roll motion. Yaw and roll signals are produced by sensing devices attached to both of the gyroscope's axes. These signals are fed to the CALIBRATOR to be converted into signals for controlling the vertical pointer of the INDICATOR during the pull-up maneuver. The ACCELEROMETER consists of a spring-suspended mass which is immersed in an oil bath. It senses the vertical accelerations of gravity. The signals generated by this unit are also fed to the indicator by way of the calibrator, and show up as horizontal deflections of the horizontal pointer.

The INDICATOR functions as a flight instrument by which the pilot maneuvers the aircraft throughout the loft bombing attack. During the run-in part of the attack in which straight level flight is required, the vertical pointer indicates roll and the horizontal pointer indicates pitch to the pilot. The information causing the deflection comes from the vertical gyroscope. As the pull-up is started, the circuits of the pointer are automatically switched. Now, during the remainder of the attack, the horizontal pointer indicates vertical accelerations and the vertical pointer shows both roll and yaw. These indications come from the accelerometer and the yaw-roll gyroscope, respectively. In the pull-up attitude, both roll and yaw errors require the same corrective motions by the pilot. Hence, both these errors are indicated on one pointer—the vertical pointer. This is an aid to the pilot as he does not have to shift his eyes to another pointer during this critical period and simply keeps the pointers "centered."

The CALIBRATOR contains all of the relays and circuits utilized during the pull-up part of the maneuver. It receives various signals and sends out other composite signals. The indicator light in the cokpit is also energized from this unit.

The low altitude bombing system (LABS) may be used for either loft or over-the-shoulder bombing as previously mentioned. Should the pilot miscalculate his initial point (landmark) on a loft bombing attack, he may still complete the attack as an over-the-shoulder maneuver and safely retire. The normal loft bombing attack is shown in figure 8–5, and the normal over-the-shoulder attack (or missed loft attack) is detailed in figure 8–6.

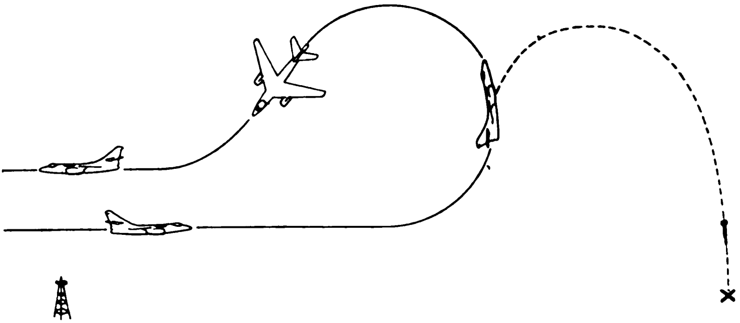


Figure 8–5.—Loft bombing attack.

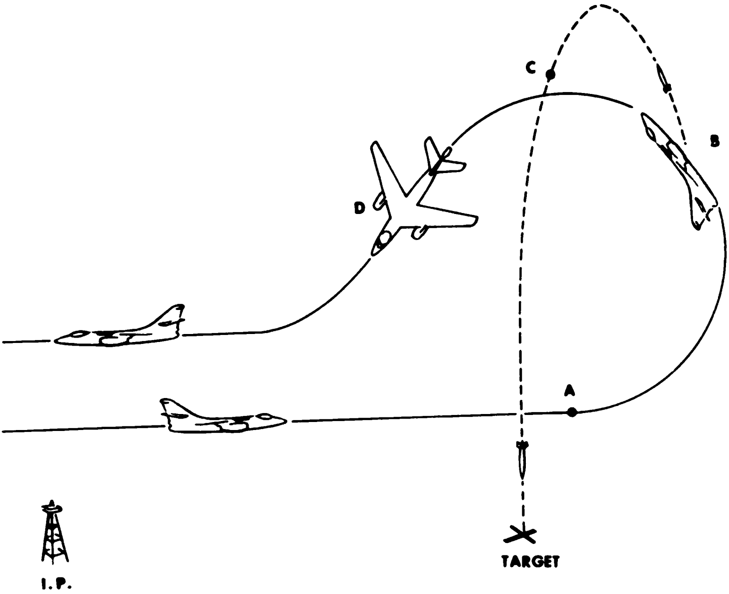


Figure 8—6.—Over-the-shoulder bombing attack.

High Altitude Bombing Directors

The high altitude director systems are vastly more complicated than the low altitude systems. However, he high altitude systems will perform a number of functions not possible with low altitude type. The primary function of the high altitude bomb director is to accomplish pinpoint bombing from extreme altitudes by high-speed aircraft. It is employed normally in aircraft havng bomb bays. This equipment may also be used to navigate the aircraft, carry out search from the air, and ts tracking recorder may be operated to obtain a photographic record of either the radar or optical presentations for reconnaissance purposes.

Controls for the high altitude director have been simplified to such an extent that the operator merely uses the tracking lever to synchronize on the aim point in making the bombing run. The aim point may even be offset from the target to some clearly discernible landmark when the target is not clearly defined. The information initially set into the director plus the information supplied by synchronizing the aim point with the tracking lever is all the data needed for solution of the bombing problem. During the bombing run, the director automatically (in sequence) opens the bomb bay doors, releases the stores, and closes the doors in a minimum length of time.

The high altitude director system incorporates many admirable features. For instance, search and inspection of the target area may be made with either optical or radar elements: periscope and radar antenna, respectively. Both these inspection elements are gyroscopically stabilized so that aircraft motions do not adversely affect their tracking. This feature offers a completely stable tracking platform for the operator. There is also the feature which allows precision tracking to be performed automatically after the operator has only twice accurately positioned the crosslines of the director on the aim point. As mentioned previously, offset bombing is easily possible when the target is hidden or not clearly defined. Highly desirable evasive maneuvers may be made by the pilot during the bombing run right up to the time of release of the stores. Also, during the bombing run the aircraft may be automatically controlled by this system if and when desired. And finally, this system, through a ground position indicator, automatically furnishes navigational data in the form of direct latitude and longitude, thus indicating the aircraft's present ground position at any instant.

The basic concept of high altitude bombing involves the factors of determining the position of the target with respect to the bombing aircraft at all times during the run, and a determination of exactly where the bomb stores will strike if released at any given instant. These factors resolve into problems of tracking and determining the trajectory of the stores. The bomb director accomplishes a solution to these problems. Use is made of either the radar or optical tracking system to track the aim point. The TRACKING DATA COMPUTER and the

TABILIZING SYSTEM are used in conjunction with the ghting system. The impact point of the store, the ourse to be flown, and the store release point are con-nuously computed by the RELEASE POINT DATA COM-UTER during the run. (See fig. 8–7.) The OPTICAL YSTEM establishes the line of sight; the RADAR SYSTEM easures the slant range and relative bearing of the m point. The radar system also is fed previously com-uted values of slant range and relative bearing from he tracking data computer and the stabilizing system, espectively. The operator may make corrections for ny differences between the measured and computed val-es existing in the radar and optical systems.

The operator, by checking on either the radar or op-cal presentations, may make corrections in range and zimuth by movements of the TRACKING CONTROL. The nes of sight of both the radar and optical systems remain fixed in space regardless of the aircraft's movements about its three axes (roll, pitch, and yaw) due to he actions of three incorporated gyroscopes in the sta-ilization system. The operator's tracking corrections ause the tracking data system to generate correct track-ng data by determining the groundspeed of the aircraft ccurately. The computer also determines the airspeed rom inputs received. Wind corrections are determined rom the SUM of the tracking operations made by the perator with the TRACKING CONTROL.

By knowing the position of the target at any instant uring the approach and information as to where the tores will strike when released at any instant, the com-uting system determines the solution of exactly what oint to release the stores in order for them to hit the arget. The release point data computer system also urnishes the POSITION DEVIATION INDICATION, or changes n course, to the pilot and to the autopilot to return the ircraft to the correct course and to show the distance to he point of release. One other function of this system s to compute and send out the signals which open the omb bay doors, drop the stores, and close the doors.

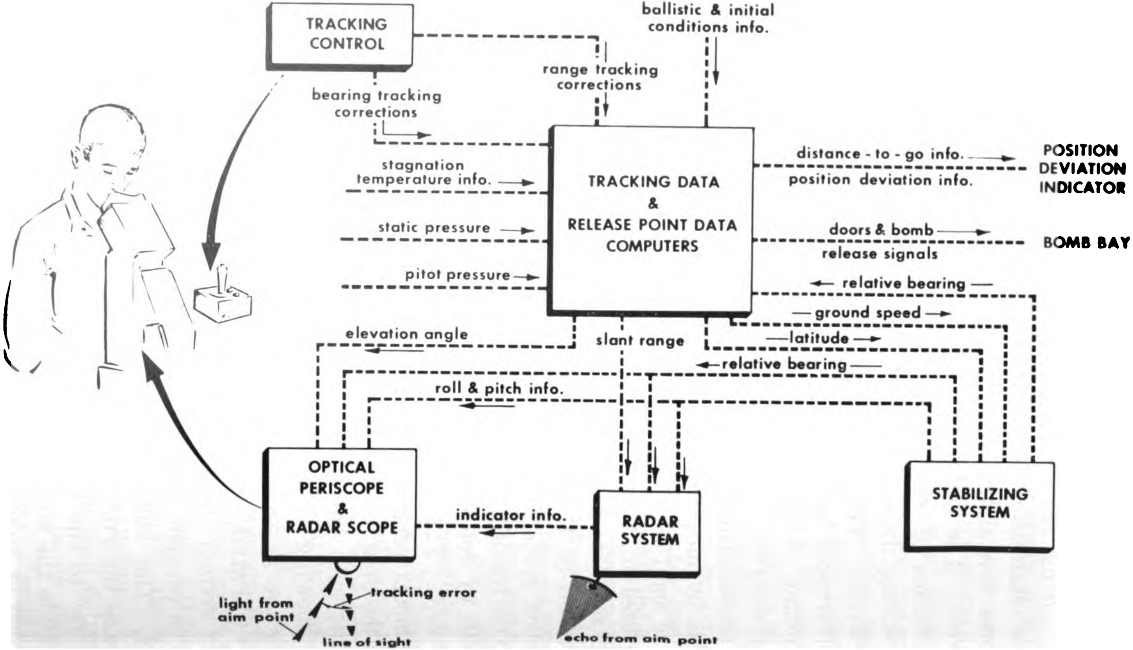


Figure 8—7.—Schematic of a high altitude bombing system.

Whenever the offset feature of the director is employed, the release point data computing system receives inputs of the offset distance and the bearing between the aim point and the target. The system then determines the target data with these inputs prior to solving the bombing problems. One other function of the computing system is generating the ground position value of the aircraft for navigational uses. Here, information as to groundspeed, course, and the initial latitude and longitude must be determined. Groundspeed and course information is generated during the tracking process, and the initial latitude and longitude is manually set in by the operator.

For a better picture of the overall functions of the various components of the high altitude bombing director, a résumé of the major ones follows.

The COMPUTER unit is the major computing element of the system. It solves the bombing problem and computes all navigational data. In order to perform these functions it measures true airspeed and altitude above sea level. It computes groundspeed and generates aircraft geographical position in terms of latitude and longitude. It generates aim point bearings, slant range, and elevation angles. It computes the position deviation angle, the distance to the target, trail, and time of fall. And finally, the computer provides the signals for bomb bay door operation and stores releasing.

The CONTROL PANEL incorporates control of power to all components of the system. It incorporates provisions for selection of either radar or optical presentations, and also selects the type of radar presentation by adjusting the radar operation. Finally, the panel offers control elements for the gyroscopes, the periscope, and the tracking recorder.

The TRACKING CONTROL is primarily used to introduce corrections in range and bearing. Its lever is used by the operator to center the radar or optical crosslines on the aim point image and/or aim point, respectively.

Depression of its rate button also introduces rate corrections.

The PERISCOPE is set so that it receives incident light from the aim point during the run and contains most of the optical elements of the system. It will be remembered that the line of sight in the periscope is positioned and stabilized by the inputs from the stabilizer system and computer. The optical system also receives radar presentations from the radar indicator. The tracking recorder, a camera, receives radar or optical presentations from the optical system and photographs either display singly or in series.

The POSITION DEVIATION INDICATOR is the pilot's source of information during the bombing run. One incorporated dial and pointer indicates the position deviation angle in degrees, while two other pointers with their common dial indicate the "distance-to-go" in nautical miles to the target.

The STABILIZING UNIT, with its three incorporated gyroscopes, establishes a stable platform for the radar and optical tracking elements of the system.

The RADAR transmits and receives radiofrequency energy to detect and display the position of the target and is also used to perform search and navigational duties.

Only the highlights of the high altitude bombing director system have been outlined in this chapter. This equipment is normally maintained, repaired, and operated by the Aviation Fire Control Technician. The Aviation Ordnanceman has little need for the detailed information commonly required by the fire control technician. However, it would be highly advantageous for any and all aviation ordnance personnel to obtain the pertinent publications on this equipment and study them with the idea of getting a more detailed knowledge of mechanical and electronic components of the system, as well as the functions of each.

EMPLOYMENT OF BOMBING DEVICES

Tactical

There are many different types of aircraft in the Navy nd each is capable of performing several tactical maeuvers. Since each type of aircraft, be it fighter, atack, or patrol, has its own set of tactical uses, it ollows that each may have its own assigned type of ombing device. Although this is not necessarily true n all instances, there are several types of bombing deices designed to perform specified tactics. This more r less restricts their employment to specific types of ircraft.

The tactical bombing maneuvers used most extensively re GLIDE, DIVE, LOFT, and HIGH AND LOW ALTITUDE. These naneuvers are engaged in by the types of naval aircraft est suited to each type of attack. The patrol aircraft, s well as other larger types, would normally engage in he high and low altitude horizontal attacks, while most f the attack class and all of the fighter aircraft would erform glide bombing, dive bombing, and/or loft bombng attacks.

DIVE BOMBING.—Dive bombing as practiced and perected originally by naval and marine pilots consisted of naking an approach at the proper altitude directly over he target from which spot a half-roll and a vertical dive vould align the aircraft with the target. It then became matter of keeping the target in the old iron ring sights ntil settled down in the dive and releasing the stores t the proper altitude. Results were considered most ccurate at that time despite the fact that there was no ready compensation for wind forcing the aircraft off its intended path to the target. The pilot had to calculate the wind's effects by seaman's eye methods. Later, telescopic sights were added to the fighters for gunnery and bombing use, but their advantages over the ring sights for dive bombing were problematical.

As aircraft weights and top speeds increased, it became impracticable, even foolhardy, to dive vertically at a target. Consequently, dive angles were reduced to the neighborhood of 60° instead of near 90°. This kept the airspeed of the aircraft in the dive to a reasonably safe figure. With this modification to dive bombing, the fixed reticle illuminated sight came into use. It gave the pilot a much clearer view of the target and rarely did he develop "target fixation" or "target hypnosis" that claimed the lives of several pilots while peeping through the restricted optical field of the telescope sight. They would become so engrossed in getting a hit that their pullout would come too late. Even with the use of this much improved sighting arrangement, the pilot still had to use the seaman's eye or a good rule-of-thumb for wind corrections. Not until the lead-computing illuminated sight came into general use did the dive bombing pilot have a reliable sight with which to make his attacks. This sight solved the problem of trying to outguess the wind direction and its strength at the various levels passed through during the dive. It also computed the necessary lead to correct for target motion. Accuracy was markedly increased.

Due to the fact that bombing tactics are continually undergoing drastic changes, dive bombing is losing favor and will most likely be supplanted by other and more effective methods. The aircraft is too easily detected and is subjected to ground fire for too long a time while in the dive.

GLIDE BOMBING.—This type of attack is rather similar to dive bombing. It might even be termed a modification of the latter. It was a later development and, as a consequence, has taken advantage of the lead-computing sight all the while. Like dive bombing, it too is a high-speed attack, but the angle of dive is 60° or less. Releasing altitudes are between 2,000 feet and 3,000 feet and the element of surprise may sometimes be gained as the dive, or glide, may be entered at a lower altitude than with dive bombing. Radar detection of the attacking aircraft may not be established in time to prevent the attack. However, once detected the glide bombing aircraft is still subjected to a rather long period of possible ground fire.

LOFT BOMBING.—For a visualization of both loft and over-the-shoulder bombing tactics, refer again to figures 8–5 and 8–6. Loft bombing is now being widely used and may eventually take the place of dive and glide bombing in a good percentage of the tactical missions. This form of attack was developed mainly to afford better chances of survival for pilot and aircraft and to utilize the element of surprise attack to the fullest extent. Since the attack is generally made at about a 500-foot altitude, radar detection is at its weakest. Terrifically high speeds common to this type of attack also aid in chances of survival and surprise to the enemy. It is necessary to have a specific type of bomb director installed in the aircraft participating in loft bombing. Most of the information governing the actual attack is set into the director prior to the mission. As soon as the pilot passes directly over a preselected landmark, he depresses a switch and holds it depressed until after the store has left the aircraft during the pull-up. Depressing the switch causes the director to compute the correct angle of release during the pull-up so that the store will be lofted to the target.

Factors in the computation of the correct release angle are aircraft speed at the instant of release and the horizontal range of the aircraft to the target also at that same instant. A miscalculated run does not necessarily mean failure of the mission, as the pilot may still place the store on the target through an over-the-shoulder maneuver after bypassing the loft bombing point of commencement. By throwing a special switch, he may shift from loft to over-the-shoulder tactics during the latter part of the approach. The director will then compute the correct release angle for this latter maneuver, giving the pilot time to retire successfully. (See fig. 8–6.)

HIGH ALTITUDE BOMBING.—High altitude or horizontal bombing may be carried out from extreme altitudes. Due to the many variables that have to be computed for use, such as trail, cross trail, trajectory, true airspeed, target motion, groundspeed, air density, temperature, plus those precomputed and furnished in tabular form, the high altitude bombing devices necessarily have to be complex mechanisms. Also, due to their bulk, they fit better into the larger patrol aircraft than they do in smaller types. The major function of high altitude bombing is to transport and release an overpowering tonnage of explosive armament on the target. To accomplish this requires large powerful aircraft equipped with bombing devices capable of pinpoint accuracy. These bombing devices also have to be self-stabilizing to such an extent that evasive action by the pilot up to the dropping point and rough air attributable to antiaircraft bursts, etc. will not destroy the accuracy of the bombing run.

Tactically, the high altitude bomber may be employed for area as well as for pinpoint bombing. The difference is mainly one of setting the intervalometers to afford different ground spacing of the stores. The nature of the target will determine which attack is to be used, as well as the type of stores to be dropped. Escape and retirement tactics have been worked out for high altitude bombing to insure that the aircraft is well away from point zero when dropping nuclear weapons.

LOW ALTITUDE BOMBING (LAB).—The bombsight as such is rapidly disappearing. Composite electronic devices which compute and control time, acceleration, yaw, pitch, and roll, are making low altitude level bombing a great deal more accurate and safely accomplished. Radar is not necessary in this type of device as it is in the high altitude type of device. It could not even be satisfactorily employed at the altitudes commonly experienced in low altitude bombing. The main advantage of this type of bombing lies in ability to deliver special weapons as a surprise on enemy installations with maximum accuracy and dispatch.

Installed in Aircraft by Type

Naval aircraft are designed to perform more than a single function or mission. Although the Navy does not have what might be termed an "all purpose" aircraft, its aircraft are capable of performing in one or more tactical areas with equal facility. There is, for instance, a twin-engine jet attack type aircraft which functions as a high and low altitude bomber, a high-speed mine layer, and may even be adapted to perform loft bombing. One jet fighter functions as a photographic reconnaissance aircraft, an interdiction fighter, a day or night light bomber, a special weapons carrier, and possibly more. Since there are several configurations possible with each service aircraft, a number of elements and components of armament, electronics, and control features are necessary in order to adapt various types of aircraft to the functions and missions required. Changing an aircraft from the performance of one function to that of another is often a matter of simply adding, interchanging, or substituting elements, components, assemblies, and subassemblies. Naturally, some changes are more complicated than others; some even requiring the assistance of an overhaul activity. However, some may be made at the squadron level.

To summarize, any aircraft may have several configurations enabling it to perform a variety of functions. In light of the above, it may be seen that arbitrarily assigning a particular bombing device to a particular aircraft does not show the whole picture as this device may be employed in other aircraft as well. However, in discussing the bombing devices EMPLOYED IN AIRCRAFT BY TYPE, the ones associated with their basic function only will be featured.

FIGHTER AIRCRAFT.—Fighter aircraft may or may not have bombing systems installed. Their functional employment will determine whether or not they will be so equipped. Low altitude bombing gear (LABS) is installed in those fighters selected for low altitude bombing assignments in addition to their other normal functions.

Installation of this gear equips the fighter to perform loft and over-the-shoulder bombing with conventional stores as well as special weapons. Those fighters not equipped with the LABS gear will perform their routine functions of gunnery, rocketry, reconnaissance, and others.

ATTACK AIRCRAFT.—Attack type aircraft perform both low and high altitude bombing. Since they range in sizes comparable to fighters and patrol aircraft, the larger types of attack aircraft are employed for high altitude bombing and the smaller ones for low altitude bombing. The high altitude bombing is performed as horizontal bombing, while the low altitude bombing is normally the loft type performed at practically "treetop" height, or, at times, glide bombing performed at low altitudes of about 5,000 feet.

The bombing gear installed in attack aircraft used for high altitude bombing offers both optical and radar target tracking, stabilization of the tracking devices of the system, selective automatic control of the aircraft during tracking, and navigational computing capabilities. The attack aircraft employed for low level, high-speed loft and over-the-shoulder types of attacks are fitted with the LABS gear. This gear is essentially a timing device interconnected to certain stabilized elements and an accelerometer and computes the correct release angle for hitting the target in both types of attacks.

PATROL AIRCRAFT.—The fast jet patrol aircraft are equipped with radar bombing and mine laying equipment which performs navigation from the starting point to a point within radar range of the target, and the final short range precision navigation (or aircraft positioning) along the release course. This system steers the aircraft and automatically drops the stores from predetermined information regarding flight course and stores dropping positions previously set into the units. Mine laying is normally carried out at rather low altitudes (200 feet to 300 feet) and at reasonably fast speeds (325 knots to 375 knots).

Other patrol aircraft contain low altitude bombing systems which are primarily used in attacks against surface vessels. However, this gear may also be used against any target visible to the radar. Still another function of this system is to fire rockets. An adapter unit is added to the system to enable it to launch the rockets. This gear establishes the closing rate between aircraft and target by furnishing a range mark. This range information, along with others of altitude and ballistics, is set into the system. From these data are computed the release range and the release time of the stores, which are automatically accomplished as the aircraft reaches the release point.

ASW AIRCRAFT.—Certain of the antisubmarine aircraft are equipped with the same low altitude bombing gear as found in the patrol aircraft. As indicated, this gear is capable of low altitude bombing and rocket launching through the use of radar and other components. Other ASW aircraft do not incorporate bombing gear in their armament control systems. They employ other means of delivering their armament which consist mainly of rockets and underwater stores.

QUIZ

1. The difference between vacuum trajectory and atmospher trajectory is known as
    a. sighting angle
    b. lead
    c. trail
    d. parabolic arc
2. The standard angular unit, a mil, is equal to
    a. 1 ft. at 1,000 ft.
    b. 3½ ft. at 3,500 ft.
    c. 2 ft. at 2,000 ft.
    d. all of the above
3. Terminal velocity is best known as the
    a. maximum speed a body will attain in an atmospheric dr
    b. maximum speed a body will attain in a vacuum drop
    c. speed a falling body attains after 320 ft. of free fall
    d. speed at which weapon hits the target
4. Radar bombsights were first developed
    a. prior to World War II
    b. during World War II
    c. just after World War II
    d. for night bombing only
5. The biggest problems to solve in developing radar bombsight were those for
    a. azimuth corrections
    b. altitude corrections
    c. range and tracking corrections
    d. locating the target
6. The primary problem solved by radar bombsights is the
    a. release range
    b. trail angle
    c. time of flight
    d. gravity
7. The search radar determines the
    a. slant range
    b. actual range
    c. whole range
    d. actual range plus trail

8. The loft bombing technique was developed with the advent of

   a. low drag bombs
   b. supersonic aircraft
   c. extremely high altitude aircraft
   d. nuclear weapons

9. As the pilot nears the target using the LABS gear, the flight instruments measure the

   a. bomb release angle
   b. angle of attack
   c. roll, pitch, and yaw
   d. G's force

0. The pilot knows his store has been released during a bombing run by a/an

   a. increase in acceleration
   b. indicator light coming on
   c. tone signal in his earphones
   d. indicator light going out

1. The release angle of the aircraft is measured by the

   a. accelerometer circuit
   b. vertical gyroscope
   c. wind vanes
   d. calibrator

2. Should the pilot making a loft bombing attack miss his initial point, he

   a. may revert to the over-the-shoulder-attack
   b. recalibrate his timing
   c. must start a new run
   d. may make a horizontal bombing run

3. In the high altitude bombing director system, the bomb bay doors are opened by the

   a. bombardier 5 miles from target
   b. director just before release
   c. bombardier just before release
   d. pilot just before release

4. The function of the radar in high altitude bombing is to measure

   a. line of sight
   b. altitude above target
   c. slant range and relative bearing
   d. true groundspeed

15. Wind corrections are determined by the
    a. navigator using the drift sight
    b. pilot visually
    c. azimuth position indicator
    d. operator with the tracking control

16. The actual bombing problem is solved by the
    a. control box
    b. computer unit
    c. tracking control
    d. position deviation indicator

17. During a dive bombing attack, windage is computed by
    a. a gyroscopic sight
    b. external wind vanes
    c. the ballistic coefficient charts
    d. the terminal velocity charts

18. Loft bombing has the advantage of
    a. high altitude
    b. very simple equipment
    c. surprise
    d. being accomplished by any type aircraft

19. High altitude bombsights have the advantage of
    a. being self-stabilized
    b. great accuracy
    c. computing all bombing problems
    d. all of the above

CHAPTER 9

SMALL ARMS RANGES

ORGANIZATION OF RANGES

Authority for Range Installation

The small arms range is a familiar physical element of the naval shore station. Its presence is more or less taken for granted by those assigned to the station and even visitors to the station. Quite often there are several ranges within the confines of the station. There may be one for rifle, another for pistol, another for automatic weapons, and still another for skeet. Certain of these types may be combined into a single range. There are other types of ranges which serve highly specialized purposes, such as those upon which turret guns may be fired and those for training troops to maneuver under actual fire. The latter types require the troops to crawl over the ground while machine guns are actually fired closely over their heads. It may be seen that the small arms ranges offer a diversified training. Although these ranges may be taken for granted by many, a great deal of planning, designing, expenditure of effort and money, and many other factors are involved in procuring authorization to construct and to operate these ranges.

Let us consider the case in which an air station had need for a new range facility, or remodeling of an old one. The commanding officer of the air station needing the small arms facility issues a directive to the Station Development Board which will prepare a basic plan for the range. This Board (fig. 9–1), in preparing the

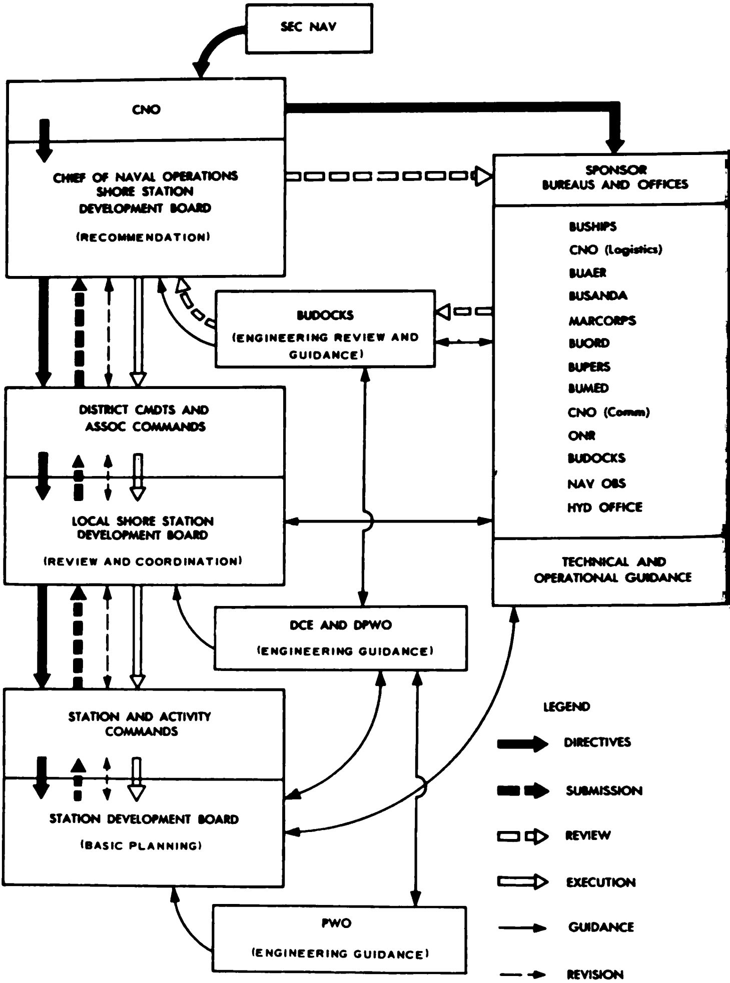

SEC NAV
CNO
CHIEF OF NAVAL OPERATIONS SHORE STATION DEVELOPMENT BOARD
(RECOMMENDATION)
SPONSOR BUREAUS AND OFFICES
BUSHIPS
CNO (Logistics)
BUAER
BUSANDA
MARCORPS
BUORD
BUPERS
BUMED
CNO (Comm)
ONR
BUDOCKS
NAV OBS
HYD OFFICE
TECHNICAL AND OPERATIONAL GUIDANCE
BUDOCKS
(ENGINEERING REVIEW AND GUIDANCE)
DISTRICT CMDTS AND ASSOC COMMANDS
LOCAL SHORE STATION DEVELOPMENT BOARD
(REVIEW AND COORDINATION)
DCE AND DPWO
(ENGINEERING GUIDANCE)
STATION AND ACTIVITY COMMANDS
STATION DEVELOPMENT BOARD
(BASIC PLANNING)
PWO
(ENGINEERING GUIDANCE)
LEGEND
DIRECTIVES
SUBMISSION
REVIEW
EXECUTION
GUIDANCE
REVISION

Figure 9–1.—Cycle of master shore station development planning.

plan, will call on the sponsoring bureau for technical and operational guidance, the District Civil Engineer, and the District Public Works Officer for engineering guidance. Of course, the local Public Works Officer (aboard the station) will also lend engineering guidance. After the plan has been drawn and revised, it is returned to the commanding officer who, in turn, submits it to the Chief of Naval Operations, via the Local Shore Station Development Board, the District Commandant (or River Command), and the Chief of Naval Operations Shore Station Development Board. In the event that the gross cost of the construction or renovation exceeds a specified figure, it is necessary to first submit plans to the Secretary of the Navy for approval. Plans for lesser amounts may be approved by the Chief of Naval Operations.

The body which reviews requests and plans for facilities and either authorizes or disallows them is the Shore Station Development Board. This Board was set up in 1947 by the Chief of Naval Operations when this office established the Shore Station Development Program The function of the Board is to plan for maintaining the shore stations in number, locations, facilities, and equipment adequate to support the Operating Forces in a constant state of readiness for war and to service the Operating Forces in the event of war.

If the plan is approved by the Chief of Naval Operations (and the Secretary of the Navy when required) and the money is available for new construction (if a new range is being built) from the Bureau of Yards and Docks, the order to execute the plan is sent back down the chain of command from the Chief of Naval Operations to the commanding officer of the air station The commanding officer is now authorized to commence construction, or to complete renovations of the range. There are certain other ramifications, but this example illustrates the routine procedure for obtaining needed facilities.

EMPLOYMENT OF SMALL ARMS RANGES.—The primary purpose of constructing small arms ranges is to afford adequate provisions for qualifying and requalifying military personnel in the safe handling and effective firing of all types of small arms. Small arms are indispensable items of warfare. Most men do not possess a native ability to handle and fire these arms properly. As a consequence, they have to be TAUGHT both these feats. To safely handle, to accurately fire, and to tactically employ these arms in a correct manner is the primary aim of all training concerned with small arms usage.

Small arms ranges of the Navy are constructed with appropriations from the Congress. Because of this fact, the Chief of Naval Operations has directed that not only shall these ranges be made available to all branches of the military but, in addition, to all able-bodied males capable of bearing arms under reasonable regulations prescribed by the controlling authorities. Hence, it is the policy to promote interest in small arms marksmanship in civilian rifle clubs and to aid in the training of civilians in the common defense of the United States. Further, commanding officers are strongly encouraged by this policy to extend the privileges of the ranges under their supervision to local police clubs, local pistol and rifle clubs of civilian membership, and other clubs chartered by the National Rifle Club of America. The only restrictions to such employment of the military ranges are that these clubs will incur no expense to the government during the course of their usage of the ranges, and that they in no manner interfere with the regular training of the military personnel.

Recruit training in small arms is conducted by the Navy so that each new member of the service is afforded the opportunity to learn how to shoot and to become proficient with these dangerous weapons. Military personnel are required to requalify in small arms at specified periods in order to maintain their proficiency. This applies to officer and enlisted personnel alike. The training must be thorough because any training in this area short of thorough is dangerous and wasteful. Certain military personnel require more advanced study and practice in the use of small arms than others. This fact exists because certain personnel, by the nature of their duties, will have more occasion to employ these weapons than others in the service. Such members will have duty in landing parties, security watchstanding, aviation and construction battalion crews, and may even be members of the Naval Emergency Ground Defense Force. About 20 percent of the naval personnel billeted ashore should be completely trained in the use of small arms as this is roughly the percentage necessary for watchstanding, and other duties of like nature.

History has clearly revealed that nations which aggressively support all types of civilian ranges have adequate ranges for the military, sponsor many marksmanship contests, and have always been outstanding in the prosecution of wars. Small arms still continue to be a heavily weighted factor in winning a war despite the tremendous increase in new and more deadly weapons. A nation with a good percentage of its population trained in effective usage of small arms is at a decided advantage over those without in the event of war and as a general deterrent to war.

The National Rifle Association of America has been supported in part by the Congress most of the years since 1902. It enjoys much prestige and vast membership throughout the United States. Its chartered clubs compete in national tournaments in which thousands of shooters compete for national honors.

In 1956 the Navy put into effect a program designed to promote more interest in marksmanship throughout the service. This new program increases markedly the number of Navywide firing competitions each year. Winners of local contests are sent to compete in other tournaments with competition increasing as each new contest is fired. The winners of the Navy contests are sent to the national tournaments. Appropriate awards and honors are made for each successful individual or team competition. To prosecute this program, all Navy range facilities have been closely checked for correct physical layout and general adaptability for competitive firing. Certain leading petty officers were selected to act as special instructors with other collateral duties. These petty officers were selected because of their interest in shooting—many of them champions in their own rights.

To further qualify these petty officers they were ordered to duty with the Marine Corps where they underwent an intensified small arms training. With this training behind them, they returned to instruct other Navy personnel at various range facilities throughout the shore establishment. Increased appropriations were made to cover the initial outfitting costs and for purposes of renovation of existing range facilities as well as construction of new facilities. In other words, the Navy has given much thought and effort and has expended a considerable amount of money in creating a permanent interest in small arms proficiency within its shore establishment. Although naval personnel learn the basic principles of small arms employment in their early service training, there has been no absolute surety that they will have the opportunity again to requalify and to maintain their proficiency in this respect during their normal tour, or tours, of duty.

Types of Ranges

After a small arms range facility has been constructed and is ready for use, it is manned by personnel assigned by the commanding officer of the station. A range officer is assigned to and made responsible for the overall operation of the range, for its internal security, and safety for all hands concerned. Ordnance strikers and rates from third class to and including chief petty officers are assigned in sufficient numbers to carry out the necessary work and to administer the details of the range. Certain members of the crew are assigned primary duties which involve instructing the trainees in the safety precautions necessary and conducting indoctrinational lectures from approved syllabi. These lectures will cover such areas as safety precautions to be employed in the use of each type of small arm, types of courses to be fired, scoring, functioning principles of the arm concerned, range etiquette, duty in the butts, proper stance and positions for firing, trigger squeeze, employment of slings, spotting scopes, pasting targets, and many other items pertinent to proper utilization of small arms.

PISTOL RANGES.—Navy pistol ranges are standardized only to the extent that they incorporate 15-, 25-, and usually 50-yard positions from which the different courses may be fired. In addition, some ranges contain a 50-foot location from which the .22-caliber pistols are fired.

The Navy pistol courses are designated L, D, E, and F. The L course is fired from the 50-foot range position with the .22 caliber pistol. (See table 9–1.) This is an INSTRUCTION PRACTICE and is not fired for MARKSMAN or EXPERT.

Table 9–1.—Course L—.22 caliber pistol.

Range (feet)	Kind of fire	Time limit	Position	Target	Shots
50	Slow—4 strings of 5.	None	Standing	B–2	20
50	Time—4 strings of 5.	20 sec. for 5 shots.	Standing	B–3	20

Total shots	40
Maximum score	400
Qualifying score	220

The D course is fired from 15 and 25 yards with the .45 caliber pistol. This course is for qualification as a PISTOL MARKSMAN. (See table 9–2.)

Table 9–2.—Course D—Pistol marksman (.45 caliber automatic).

Range (yards)	Type of fire	Time limit	Target	Shots
25	Slow	None	25-yard standard American.	10
25	Timed	20 sec. 5 shots	do	10
15	Rapid	15 sec. 5 shots	do	10

Possible score	300
Qualifying score	165

Course E is also fired from 15 and 25 yards with the .45 caliber automatic pistol, but is for qualification as PISTOL EXPERT. (See table 9–3.)

Table 9–3.—Course E—Pistol expert (.45 caliber automatic pistol).

Range (yards)	Type of fire	Time limit	Target	Position	Shots
25	Slow	None	25-yard standard American.	Standing	10
25	Timed	20 sec. 5 shots.	do	do	10
15	Rapid	10 sec. 5 shots.	do	do	10
25	Rapid	10 sec. 5 shots.	do	do	10

Total shots	40
Possible score	400
Expert (medal awarded)	300
Sharpshooter	280
Marksman	220

Course F is fired from 15 and 25 yards with the standard .38 caliber service revolver. It is fired for qualification as a REVOLVER EXPERT. (See table 9–4.)

Table 9–4.—Course F—Revolver expert (.38 caliber revolver).

Range (yards)	Type of fire	Time limit	Target	Position	Shots
25	Slow	None	25-yard standard American.	Standing	10
25	Time	20 sec. 5 shots.	do	do	10
15	Rapid	10 sec. 5 shots.	do	do	10
25	Rapid	do	do	do	10

Total shots	40
Possible score	400
Expert (medal awarded)	320
Sharpshooter	300
Marksman	280

RIFLE RANGES.—The M1 Garand rifle is the standard ifle of the Navy as well as other services. It is fired ormally for marksman and expert on ranges of 100, 00, and 500 yards. The .30 caliber carbine is also fired n the same range as the standard rifle, but at positions f only 100 and 200 yards distance from the target. The 22 caliber rifle is normally fired on a 50-foot course ither indoors or outdoors. However, certain tournaent courses for the .22 caliber rifles are fired up to 00 yards.

Course K is fired from 50 feet using the .22 caliber ifle with sling. It will be noted that this course is the ecord .30 caliber course B in miniature. (See table –5.)

Table 9–5.—Course K—.22 caliber rifle.

Range (feet)	Time limit	Shots	Target	Position	Sling
0	None	4	SB–A–2	Standing	Hasty.
0	None	4	SB–A–2	Sitting	Loop or hasty.
0	None	4	SB–A–2	Kneeling	Loop or hasty.
0	None	8	SB–A–2	Prone	Loop.
0	40 sec. 8 shots.	16	SB–D–2	Sitting from standing.	Loop or hasty.
0	40 sec. 8 shots.	16	SB–D–2	Kneeling from standing.	Loop or hasty.
0	45 sec. 8 shots.	16	SB–D–2	Prone from standing.	Loop.

otal shots, each firing	68
otal shots, two firings	136

Course A is fired from 200 yards with the M1 .30 aliber rifle. This course may be fired once for practice and the second time for record. It is only intended for a preliminary course prior to firing the expert course (Course B). (See table 9–6.)

Table 9–6.—Course A—Rifle marksman.

Range (yards)	Time limit	Shots	Target	Position	Sling
200	None	4	A	Standing	Hasty.
200	None	4	A	Sitting	Loop or hasty.
200	None	4	A	Kneeling	Loop or hasty.
200	None	8	A	Prone	Loop.
200	30 sec.	8	D	Sitting from standing.	Loop or hasty.
200	35 sec.	8	D	Prone from standing.	Loop.

Total shots record firing	
Maximum score	18
Qualifying score (no medal awarded)	1

Course B is fired from 100 and 200 yards with the .30 caliber carbine and from 100, 200, 300, and 500 yards with the M1 .30 caliber rifle. In the rapid-fire stages the firer is required to remain standing with the rifle at the READY until the targets appear while firing the M1 rifle. It will be noted that slings are NOT to be used in firing the courses with the .30 caliber carbine. (See table 9–7.)

Course C is fired from 100 and 200 yards with the .30 caliber carbine and is fired once for preliminary record practice. (See table 9–8.)

AUTOMATIC WEAPONS RANGES.—The automatic weapons fired on these ranges are the Thompson submachine gun, the Browning automatic rifle (BAR), the .30 caliber machine gun, and the .50 caliber machine gun. The submachine gun is fired from 25, 100, and 200 yards. The Browning automatic rifle is fired from 200 and 500 yards, the .30 caliber machine gun, and the .50 caliber machine gun are fired from a short range of 200 yards up to and including 1,000 yards.

Course G is fired from 25, 100, and 200 yards with the Thompson machine gun, caliber .45. First, this

Table 9–7.—Course B.

(1) Rifle expert (M1 .30 caliber).

Range yards)	Time limit	Shots	Target	Position	Sling
0	None	4	A	Standing	Hasty.
0	None	4	A	Sitting	Loop or hasty.
0	None	4	A	Kneeling	Loop or hasty.
0	60 sec.	16	D	Sitting from standing.	Loop or hasty.
0	60 sec.	16	D	Kneeling from standing.	Loop or hasty.
0	65 sec.	16	D	Prone from standing.	Loop.
0	None	8	B	Prone	Loop.

tal shots, record firing	68
aximum score	340
pert (medal awarded)	306
arpshooter	292
arksman	268

(2) Instruction Practice (.30 caliber carbine).

Range (yards)	Time limit	Shots	Target	Position
0	None	10	A	Prone.
0	None	10	B	Prone.

(3) Instruction Practice (.30 caliber carbine).

Range (yards)	Time limit	Shots	Target	Position
00	None	5	A	Sitting.
00	None	5	A	Kneeling.
00	None	5	A	Standing.
00	None	5	B	Prone.
00	None	5	B	Sitting.
00	None	5	B	Kneeling.
00	None	5	B	Standing.

Table 9–8.—Course C—Carbine record practice.

Range (yards)	Time (sec.)	Shots	Target	Position
100	40	8 (2 magazines 4 each).	A	4 rounds standing; reload, take sitting position, fire 4 rounds.
100	40	do	A	4 rounds standing; reload, take kneeling position, fire 4 rounds.
200	40	do	B	4 rounds standing; reload, take sitting position, fire 4 rounds.
200	40	do	B	4 rounds standing; reload, take kneeling position, fire 4 rounds.
200	40	do	B	Standing to prone, fire 4 rounds, reload, fire 4 more.

Total shots, instruction practices	170
Total shots, record practice	40
Maximum score for record	200
Qualifying score:	
Expert (medal awarded)	180
Sharpshooter	165
Marksman	140

course should be fired for instruction and second, for record. (See table 9–9.)

Course H is fired from 200 and 500 yards with the .30 caliber machine gun. It is fired as a record practice. (See table 9–10.) However, instruction practices may be fired within the discretion of the officer in charge of the practice and within the ammunition allowances available.

Course I is also fired from 200 and 500 yards, but with the Browning automatic rifle. While instruction practices are not specified, they should be conducted within the ammunition allowances at the discretion of the officer in charge of the practice. (See table 9–11.)

Course J is fired from 200, 400, 600, 800, and 1,000

Table 9–9.—Course G—Submachine gun.

Range (yards)	Kind of fire	Time limit	Target	Position	Shots
200	Slow	None	B	Prone	10
100	Semi-automatic.	25 seconds	3, A*	Standing or sitting.	10
25	Automatic	10 seconds	3, A*	Standing; gun at hip until commence firing.	15

*NOTE: For 100-yard range use 3 of the A rifle targets, 10 feet apart. Distribute fire. Deduct 10 points for any target not hit inside the 4 ring. No hit outside the 4 ring is scored. In applying penalty, no score will be less than zero at any one range. For 25-yard range use 3 of the A rifle targets, 5 feet apart, with the same penalties as described above.

Total shots, instruction practice	70
Total shots, record practice	35
Maximum score, record practice	175
Qualifying score	100

Table 9–10.—Course H—Ground machine gun (record practice).

Range (yards)	Kind of fire	Time limit	Target	Shots
200	Burst of 3 to 5	None	B	10
200	do	35 seconds	B	20
200	do	20 seconds	B	20
500	do	None	B	10
500	do	40 seconds	B	20
500	do	20 seconds	B	20

Total shots	100
Maximum score	500
Qualifying score	260

yards with the .30 and .50 caliber machine guns. The target consists of strips of target cloth 100 yards long by 2 yards high. These targets are set up parallel to the beach and supported by vertical stakes. They are subdivided into sections A, B1, B2, C1, C2, and D. This course is designed as an instruction practice for gunners of machine guns mounted in landing craft. Both .30 caliber and .50 caliber guns may be used. Proper dis-

Table 9–11.—Course I—Automatic rifle (BAR).

Range (yards)	Kind of fire	Time limit	Position	Target	Shots
200	Single shots	None	Prone, sandbag rests.	B	10
200	Semi-automatic.	20 sec.	Prone	B	10
200	do	25 sec., 10 shots.	Sitting	B	3 strings, 10 shots each.
500	Single shots	None	Prone	B	10
500	Semi-automatic.	1 min., 20 sec.	Prone	B	40

Total shots	100
Maximum score	500
Qualifying score	300

tribution of fire during the approach to the beach is the most important feature of the course. Firing the course should be preceded by mechanical training and instruction in the manipulation of the gun and at least one firing of Course H ashore for familiarization. No record practice or qualifying is prescribed pending the receipt of sufficient reports, comments, or recommendations upon which to base an analysis. (See table 9–12.)

Table 9–12.—Course J—Boat machine gun.

Range (yards)	Type of fire	Target	Time (sec.)	Shots
1,000–800	Bursts of automatic	A, B, C, D, distributed.	30	50
800–600	do	do	30	50
600–400	do	do	30	50
400–200	do	B, C	30	50
200 to beach.	do	D, distributed	20	50

GENERAL CONSIDERATIONS.—Specifications for the construction of small arms ranges for the Navy are available. These specifications give in detail the basic range construction with regard to size; measurements of firing positions from the targets; shape, size, and facial inclination of the bullet stop (butt); layout of range components in general; desired terrain (natural) conditions; and other considerations of range installation. Once the range facility is constructed and in use, upkeep and maintenance then become the primary considerations.

A well-kept small arms range is an asset to any naval station. To maintain a range properly will assure that it always has a well-kept and neat appearance. Maintenance on all types of small arms ranges varies only to a minor degree. Such variance existing is usually brought about by the relative sizes of the ranges. It is somewhat harder to maintain a rifle range which may extend over several hundred yards than it is to perform the same type of work on a pistol range which covers from 25 to 50 yards.

Targets for small arms firing are all of prescribed dimensions for the types of arms and the courses to be fired. The devices which support and display the targets and placed in the butts are not standardized to any particular degree. Basically, the supporting devices are constructed from wood in those parts which show above the ground level and are consequently exposed to fire. Those parts below ground level in the butts are quite often constructed from angle iron and pipe. The wooden frames above the ground are faced with a material similar to cheesecloth to which the targets are secured. Certain ranges incorporate target supports which may be rotated from the firing line. Maintenance to the target supports consists mainly of repairing or replacing the wooden frames when damaged by gunfire.

Rifle ranges incorporate a trench (known as a pit) parallel to the butts which allows personnel to remain at the targets during firing in order to mark and paste the targets. This pit is deep enough to protect even a tall man while standing. In spite of this depth of pit, there is normally a low mound of earth near the firing line side of the pit for added protection. A telephone system is installed between the firing line and the butts. This system acts both as a safety device and a means of expediting the firing of the courses. Personnel in the butts during firing are under the direct supervision of an experienced man (chief pit officer) who directs their activities from his position in the butts in accordance with instructions given by the range officer at the firing line. He also insures that all safety precautions are strictly observed by the personnel in the butts attending the targets. Machine guns may also be fired on this type of range. Targets and firing procedures will necessarily have to be altered to the appropriate ones for the machine gun.

The areas between the firing positions and the targets of the pistol ranges are, where practicable, sodded or planted with some specie of vegetation which will grow best in that particular climate. Occasional trimming and watering is necessary to keep this vegetation at its best, both for appearances and for its ability to slow down wild shots which may strike the ground short of the butts. Rifle ranges which extend over several hundred yards need not be sodded. Usually, natural wild vegetation will take over a newly constructed range and has to be kept trimmed for neatness and good visibility of the targets.

The shooting positions, or firing lines, are quite often elevated above the surrounding areas for reasons of good drainage after rains and for better visibility. They are smooth, level, and at exactly the prescribed distances from the targets.

There are many other features of the range which add to the effectiveness of the range and the comfort of the shooters. Benches, water fountains, sunshades, gunracks which may be transported from course to course, sidewalks, stands for arms and ammunition, firing line canopies, range officer's stand, range buildings, and protective bulkheads are some of the features often added to the basic range design.

In general, maintenance of all types of ranges consists of repairs to and painting of wooden components, repairs and painting of metal components, regular policing of the areas for trash and articles adrift, trimming of grass, replacement of targets and their cloth supports, and repairs and lubrication of any mechanical features incorporated.

Indoctrination and Instruction

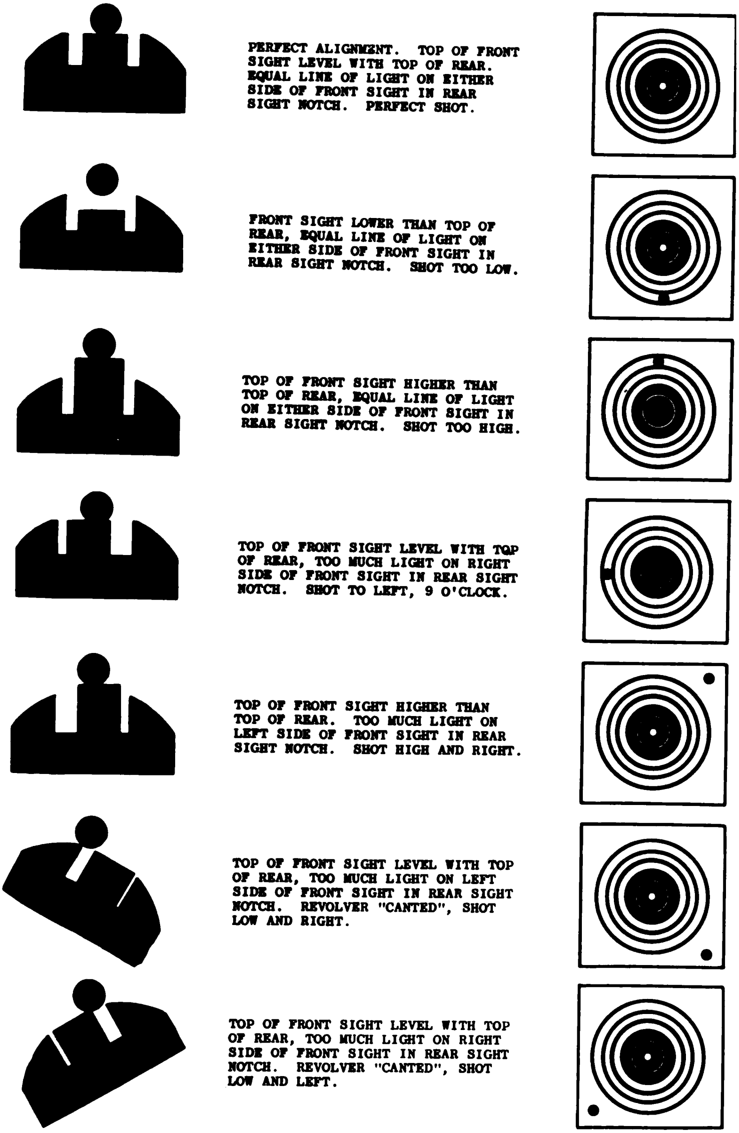
There is an old saying that "good shots" are born. We know today that this is not quite the truth. The methods by which service personnel have been taught to accurately fire all types of small arms have been thoroughly tested over the years. One conclusion to be drawn from records kept by the services is that anyone may be taught to shoot accurately. There is no denying that perfect coordination of muscles, nerves, brain, and eyes materially aid in shortening the training period necessary to produce a highly qualified shooter. But by proper training, anyone may become a good shot.

Quite often the major hindrance to a person becoming a good shot stems from bad shooting habits picked up through self-instruction. A person with this trouble attempting to qualify in small arms will have a harder time than a person who never had a gun in his hand. The bad shooting habits have first to be completely eradicated by the instructor before the self-instructed shooter is finally on an even footing with the rank beginner. It has been proven many times that, with the present training methods, the man who has developed bad shooting habits may successfully be "converted" into a good shot.

The services have found that ONE method of instruction should be used. Although another method might prove just as effective, it is not a good idea to use two methods of training because a great loss of time and effort is caused by transfers from one method to the other. For this reason, one method has become standard throughout the services.

PREPARATORY EXERCISES.—Essential operations in these exercises are taken up in a specific order. The first exercise is to learn the proper alignment of the sights of the small arm. Basic principles of correct sighting are shown in figure 9–2. Although this figure depicts side arm sights, the same sighting principles hold for any small arm with open sights. After mastering this, proper holding of the arm is taught. After this comes the trigger squeeze. This is quite often the most difficult of all phases to master, but it is the most important of all. Each phase above has to be mastered to the extent that it may be performed without completely absorbing the attention of the trainee from the other phases which have to be performed concurrently. This is a fine point of instruction in the overall picture. Each new step is added to the previous one in practicing so that the earlier steps are not forgotten and the trainee may see and feel how each step leads to the next. Then, manipulation of the arm and firing exercises follow. Finally, an examination is held which covers all that has previously been given and learned. The trainee is not allowed to go on to the firing phase of training until he has mastered all the preparatory exercises.

In the firing phase of instruction, there are still preparatory exercises to be learned before actual firing of the arm is permitted. The principles of good shooting and performance of all essential operations are again studied. Only after the instructors are sure that all trainees have learned all preparatory exercises so that they can perform them without hesitation will they be allowed to load ball ammunition and fire at targets. It has been found essential that the trainee be taken from the preparatory phase into and through the firing phase without a break in his instruction. The combined effect of both the preparatory exercises and the range firing is necessary for the formation of correct shooting habits.



PERFECT ALIGNMENT. TOP OF FRONT SIGHT LEVEL WITH TOP OF REAR. EQUAL LINE OF LIGHT ON EITHER SIDE OF FRONT SIGHT IN REAR SIGHT NOTCH. PERFECT SHOT.

FRONT SIGHT LOWER THAN TOP OF REAR, EQUAL LINE OF LIGHT ON EITHER SIDE OF FRONT SIGHT IN REAR SIGHT NOTCH. SHOT TOO LOW.

TOP OF FRONT SIGHT HIGHER THAN TOP OF REAR, EQUAL LINE OF LIGHT ON EITHER SIDE OF FRONT SIGHT IN REAR SIGHT NOTCH. SHOT TOO HIGH.

TOP OF FRONT SIGHT LEVEL WITH TOP OF REAR, TOO MUCH LIGHT ON RIGHT SIDE OF FRONT SIGHT IN REAR SIGHT NOTCH. SHOT TO LEFT, 9 O'CLOCK.

TOP OF FRONT SIGHT HIGHER THAN TOP OF REAR. TOO MUCH LIGHT ON LEFT SIDE OF FRONT SIGHT IN REAR SIGHT NOTCH. SHOT HIGH AND RIGHT.

TOP OF FRONT SIGHT LEVEL WITH TOP OF REAR, TOO MUCH LIGHT ON LEFT SIDE OF FRONT SIGHT IN REAR SIGHT NOTCH. REVOLVER "CANTED", SHOT LOW AND RIGHT.

TOP OF FRONT SIGHT LEVEL WITH TOP OF REAR, TOO MUCH LIGHT ON RIGHT SIDE OF FRONT SIGHT IN REAR SIGHT NOTCH. REVOLVER "CANTED", SHOT LOW AND LEFT.

Figure 9–2.—Effects of correct and incorrect sight alignments.

FIRING PROCEDURES.—Safely conducting a small arms practice of record firing requires a definite set of firing procedures. This is true whether qualifying trainees or requalifying more experienced men. FIRING COMMANDS have to be given in order to insure that all men on the firing line will do the same thing at the same time and with the maximum safety possible. These commands have to be given in a loud clear voice and in language easily understood by all hands concerned. The trainees are familiarized with such commands throughout their class room and range work.

There are more or less standard commands to be given by the range officer or petty officer conducting the practice or qualification firing. These commands will vary from one small arms facility to another, and for different types of weapons being fired. As a result, no cut and dried set of commands exist as such.

Basically, the initial command given prepares the firers for shooting by ordering them to load and lock their pieces. After it has been established that this command has been executed by ALL on the firing line, a command is given to unlock and fire the weapons. Upon completion of firing, or after a specified time interval, all hands are commanded to cease firing and safety their pieces. The basic commands may be used for all types of small arms firing. However, they must be amplified to meet the exact needs of the various types of courses to be fired, types of weapons being fired, and to prescribe to local conditions.

An example of the commands given during a pistol firing, for instance, may be as follows:

Command	*Action*
1. "First relay on the firing line."	First relay previously assigned take positions on firing line.
2. "Load magazines with _____ rounds."	This command may not be necessary due to having preload magazines available.

Command—Con.	*Action*—Con.
"Load and lock."	Firers face the butts, pick up their weapons, load and "safety" them according to the type of weapon used.
"Ready on the right."	Firers to the right of the range officer are checked to insure that their pieces are ready for firing. If a firer on the right has a jam, other malfunction of the piece, or, for some reason, is not ready, he holds up his LEFT hand and the practice is interrupted. If no signal is seen by the range officer, he assumes that all to his right are ready to fire.
"Ready on the left."	The same procedure applies here as in 4 above. When the range officer, looking both to right and left now, is sure all firers are ready, he gives his next command.
"Ready on the firing line."	Firers unlock their weapons and bring them on the targets so that without hesitation the first round may be fired on hearing the next command.
"FIRE."	Firing now commences in accordance with previously determined plan. The type of fire may be slow, timed, or rapid.
"Cease fire—clear and lock pieces."	Each firer stops firing the instant he hears this command, keeps his weapon pointed at the butts, removes magazine and/or unspent rounds, checks breech to insure that it is clear, and safeties the piece. Finally, he places the weapon on the rest and steps back one pace.

The range officer may then command the firers to go forward to either mark or observe marking of their targets, depending on the progress of the exercise being fired. A jammed weapon during the course of firing an exercise is handled in accordance with instructions given in class or prior to going on the firing line.

One safety feature which is INVARIABLY USED AT ANY AND ALL SMALL ARMS RANGES DURING FIRING is the raising of a red flag (Bravo flag) over the range. This flag, at the peak of its mast, is clearly visible to all at, near, or approaching the range facility.

The monotony of repeating a simple operation is a limiting factor in the length of time a trainee should be forced to continue preparatory exercises. Roughly, 15 or 20 minutes at any one time is all a trainee will be able to practice aiming, holding, and dry firing the gun. Skillfully introduced changes to procedure by the instructor may materially lengthen this period of attentiveness. The idea is to compel the trainee to perform the exercises until all actions become habitual without causing the whole instruction to become a monotonous and distasteful task. Two weeks of continued practice is considered a minimum in which to prepare the trainee for actual firing and to form correct shooting habits. Some will require more time. Even though the manner of correct performance of the essential operations has been thoroughly learned, the trainee will take at least a week on the firing line to solidly fix the habit of correct performance of these operations within his mental and physical makeup.

During small arms instructions the trainees are divided into pairs; one is the "firer," the other the "coach." The instructor alternates the trainees between these two jobs. The "coach" observes the performance of the "firer" and vice versa. This routine provides frequent changes in procedure which prevent loss of interest, constant supervision of a personal nature, corrects bad habits as they show up, shows the trainees graphically their own mistakes, and tends to develop the ability of the trainees as instructors.

Another division that is necessary among the trainees is that of forming a number of GROUPS of convenient size to be adaptable to the best training procedures. A squad similar to that found in the Navy Emergency Ground Defense Force (NEGDF) is considered to be highly adaptable. Each group is under the direct supervision of a group instructor who is usually a petty officer from the same division as the men under instruction. These group instructors are, or should be, specialists trained in the instruction of small arms. Over these instructors will normally be an officer in charge of instruction who coordinates all instruction and lays out the work.

The methods of instruction are standardized in three steps: First, to explain to the men under instruction the reasons for the training as well as the necessity for it; second, to give a demonstration of the work to be covered by steps; and third, to exercise the men in work laid out for the steps. Step one tells the men what they should do—not what they should avoid—and stresses the necessity for exactness in the performance of all operations. Step two establishes a routine in which the men are divided into pairs and each man in these pairs alternates in the performance of the exercises. Finally, step three carries out the exercises by groups under group instructors in the same manner as has been demonstrated previously. Close supervision is given by the group instructors and the officer in charge of instructions.

SMALL ARMS EMPLOYMENT.—Not all naval personnel are instructed and qualified in all types of small arms. This is not practicable. However, some personnel, due to their presumptive duties, will receive the full course of instructions in all types of small arms. It may be said then that the average man will receive training and qualify in one or more types of small arms. Recruits at training stations are given a thorough course in rifle marksmanship. All other men entering the service should get this training also. The types of small arms used by the Navy are the rifie, revolver, pistol, carbine, submachine gun, automatic rifle, machine gun, and the shotgun. Some of these general classifications of small arms have one or more differing types of arms under each classification. A description of all the small arms used by the Navy will be found in *Aviation Ordnanceman 3 & 2*, Volume 2, Chapter 1, NavPers 10346.

Small Arms Firing

Each type of small arm requires a different technique in being properly fired. However, if one is to effectively fire any piece, it is necessary to master certain basic techniques common to the firing of all small arms. The proper trigger squeeze, the assumption and holding of proper firing positions, correct sighting, and muscular relaxation are basically the same for all firing. The standing positions from which to fire the pistol and the rifle are not identical, of course. But they are basically enough alike to be treated the same as far as stance and trigger squeeze and relaxing of muscles are concerned. A person who masters these basic techniques is well on his way to becoming a good shot with any type of small arm.

REGULATIONS AND RESPONSIBILITIES.—In the firing of small arms, certain regulations and responsibilities immediately become importantly evident. The discharge of any weapon in populated areas has to be strictly supervised. Someone must set forth the regulations covering the firing, see to it that they are scrupulously carried out, and assume the responsibility for safety to all hands.

REGULATIONS may consist of anything from orders for posting range sentries to the proper manner in which to fire from the prone position. While firing positions may be thought of as techniques or procedures, they are still standardized regulations. These positions have en developed after much experimentation and are gulations to the techniques of correct firing. Other gulations are concerned with the manner in which ch small arm is to be handled and fired; the exact stances over which various courses are to be fired; the fety precautions pertinent to arms, ammunition, and e handling of both; and the number of hours, or udy sessions, necessary to prepare the trainee for the ing phase of small arms qualification. There are a ultitude of others, but the above indicate the diversity their coverage.

Some of these regulations originate from the Secretary the Navy. Such general regulations and responsi-lities will be found in the *Landing Party Manual, ited States Navy 1950.* Others come from the Bureau Ordnance and District Commandants. Still others iginate at local levels, such as commanding officers naval stations having small arms ranges. Even the ficer in charge of the range will feel the need for rtain regulations covering specific local conditions. uite often even the instructors will see similar needs. hen drawn up and duly authorized by the commanding ficer, they become just as much a part of local regula-ons as do those from higher authority.

RESPONSIBILITIES connected with administration and eration of a small arms range are not all assignable any one person although the officer in charge of the nge has the final responsibility, to the commanding ficer, for the range. Responsibility for safety and e proper conduct of firing exercises lie with ALL HANDS ncerned. If a "coach" notices a dangerous situation the firing line, it is his responsibility to take im-ediate steps to correct it. If the group instructor otes an omission in the training syllabus, it is his sponsibility to bring it to the attention of the officer charge of instruction or the officer in charge of the nge. Among his other responsibilities, the range of-cer is responsible to bring to the attention of his com-anding officer any discrepancies noted in the overall physical plant, shortcomings in the training, and oth personnel and material problems. These are all merel examples to illustrate the fact that acceptance of an attention to responsibilities are mandatory to all hand concerned with any undertaking.

The range officer delegates authority down the lin Those involved automatically accept certain responsibilities in connection with the authority delegated t them. On the proper discharge of these responsibiliti depends the successful conduct of the undertaking.

Small Arms Targets

Two general types of small arms targets are used i the Navy. They are those for SMALL BORE shootin and those for all other small arms shooting. The smal bore arms are the .22 caliber pistol and rifle. The smal bore targets are the SB–A–2, Gallery Rifle Targe which is a miniature of the Rifle A target; the SB–D– Gallery Rifle Target, which is a miniature of the Rifle Target; the Official 50-foot Gallery Rifle Target; th Official 50-foot B–2 (Slow Fire) Gallery Pistol Target and the Official 50-foot B–3 (Rapid Fire) Gallery Pisto Target.

The targets for .30 caliber and larger arms are th Rifle A Target which has a 10-inch diameter bull's-ey and is 6 feet high and 4 feet wide; the Rifle B Targe which has a 20-inch diameter bull's-eye and is 6 fee square; the Rifle D Target which has a silhouette 2 inches by 19 inches; and the Standard American Pisto Target which has a 10-ring diameter of 3.39 inches.

The standard American Pistol Target is used whe firing the .22 caliber, .38 caliber, and .45 caliber pistols When fired from 25 yards, the 3.39-inch 10-ring is used for the bull's-eye. When fired from 50 yards with the same weapons, the 8-ring forms the outside diameter of the bull's-eye. The Standard American Pistol Target as the name might suggest, is also used by the National Rifle Association as standard for pistol firing. The hompson .45 caliber submachine gun is fired at the 6- by 19-inch silhouette target (Rifle D Target) usually t a distance of 25 yards. The Browning automatic fle is fired at the Rifle B Target which has a 20-inch ıll's-eye. It may also be fired at the 26- by 19-inch lhouette target. The .30 caliber carbine is fired at oth the Rifle A and the Rifle D Targets.

TARGET MATERIALS.—The Navy stocks certain standard ems of target material which may be requisitioned as escribed by the *Bureau of Supply and Accounts Manl.* The points from which these materials are reqsitioned are the Ordnance Supply Depots at Norfolk, irginia; Oakland, California; and Pearl Harbor, T.H. he standard materials stocked consist of repair target nters, target cloth, different sized target spotter disks, mplete target frames, complete target markers (short ıd mid ranges), dry target paste, black and buff target ısters, and target spotter spindles. Items that are not standards stock lists may be requisitioned; however, ıere must be approval from the Chief of Naval Operaons on the requisition.

MAINTENANCE AND EMPLOYMENT.—In order to use ıe various targets on the rifle range, it is necessary attach them to target frames. This is usually acmplished by pasting or using a staple gun. The ames are then set into their metal supports, two to supporting device. These devices are constructed so ıat the targets may be easily raised and lowered at ill. The weight of one target frame counterbalances ıe weight of the other, thereby necessitating a minimum effort in raising one and lowering the other. The ıpporting device (target carriers) is fashioned from on angle members and plating. A system of sprocket heels and chains raise one target while lowering the her as the frames ride in channels provided to assure lequate rigidity and ease of operation. Metal strucıres are always placed below the line of fire down in ıe butts to prevent dangerous ricochets.

A well-organized and smoothly operating range will have sufficient targets of all kinds, paste, target spotter disks, spindles, cloth, pasters, and other devices on hand and ready for use. Closely adjacent to each man marking targets should be sufficient materials needed to "paste" targets. These materials should be neatly stowed in a box or on a ledge where they will not become adrift and where they may be protected from deterioration As the targets are pasted one over the other during firing, care should be exercised not to allow them to build up to a point at which they become too heavy and start to peel or fall off. Remove the old ones prior to that time and replace them with a new single target. While pasting or fastening targets to their frames with a staple gun, insure that they are securely fastened against wind damage.

It may be necessary to replace the target cloth fastened to the target frames after many punctures by the projectiles. This material is cut and fastened to the wooden frames with staples. Also, the frames themselves are heavily damaged by gunfire. They should be replaced before they become unfit or dangerous to use All metal frictional surfaces should be well lubricated and other portions preserved to prevent rust. Pistol ranges often have been fitted with means of moving the targets 90° from the line of fire remotely. These devices are constructed of metal in the main and have to be hidden low in the pit to prevent accidental ricochets. Only the targets and their wooden frames show above ground as with the rifle target devices.

Good working conditions aid in smooth operation of a range. Therefore, it is necessary to police the areas including the butts and firing lines at intervals during the progress of an exercise. Old targets, pasters, wooden splinters, and other debris should be systematically cleaned up—not allowed to accumulate. "Brass" on the firing lines will be picked up periodically and placed in receptacles provided for the purpose of saving the spent cases. Areas between the firing lines and the butts and adjacent thereto should be kept clean of paper, trash, undergrowth of sufficient height to bother the firer, and other foreign articles. Neatness of the range devices and structures is heightened by painting. Painting also serves the important task of helping to prevent corrosion of metal parts and rot in wooden fabrications. Grass and other vegetation is very helpful in stopping wild shots. It should, therefore, be encouraged to grow into thick carpets between the firing lines and the butts.

Small Arms Ammunition

Ammunition for preliminary training and for qualifications is limited. Only certain allotments can be made for the above purposes; therefore, all ammunition for small arms training must be wisely expended. It is necessary that preliminary training be conducted with great care and thoroughness so that firing for qualification may be performed without exceeding allowances. The basic training allowances of ammunition for marksmanship are:

Course A—Rifle marksman, and Course B—Rifle expert	400 rounds
Course C—Carbine	210 rounds
Course D—Pistol	200 rounds
Course E—Pistol	200 rounds
Course F—Revolver	240 rounds
Course G—Submachine gun	105 rounds
Course H—Ground machine gun	400 rounds
Course I—Automatic or semiautomatic rifles	300 rounds
Course J—Boat machine gun	500 rounds
Course K—.22 caliber rifle	150 rounds
Course L—.22 caliber pistol	60 rounds

The above allowances have changed from time to time. Accordingly, all pertinent current instructions should be read to establish the actual amounts authorized to be expended. The above figures do not include that ammunition allowed for various official competitions.

Ammunition used for practice, for record firing, and unless otherwise authorized, for competitions is the regular ammunition issued to ships and shore stations and designated for such use by the Bureau of Ordnance.

The ammunition issued by the Bureau is necessarily of many different lot numbers. Therefore, it is highly desirable that the same lot number ammunition used by a particular individual in his practice firing ALSO be used for his record firing. Consistent results in firing are much easier to obtain using the above procedure than when the lots are mixed for practice and the record firing. When competitions are fired, it is only fair that ALL contestants be issued the same lot number ammunition. It has been found through experience that there is a definite relationship between the thoroughness of the preliminary training of the individual and the average number of rounds he needs to actually qualify. Good training in the preliminary stages usually prepares the man to qualify by expending the absolute minimum number of rounds.

In controlling small arms ammunition, the Bureau of Ordnance screens reports of ammunition from the field for evidence and cause of its becoming unserviceable. Dispatches are sent to commands known or suspected of having defective ammunition. These dispatches suspend from issue, by lot number, all such ammunition deemed unserviceable. Subsequent instructions from the Bureau order specific disposition of the defective lots. Publications are issued which set up allowances of ammunition for everything from the various services down to the individual man. The Navy and the Marine Corps will have established for them certain allowances of ammunition, service teams at competitions will have certain allowances, and an individual representing the service at a competition will have a specified allowance of rounds. Allowances are set for all contingencies. NavOrd Lists are the authority for such allowances. NavOrd Instructions contain further breakdowns of allowances for specific instances and conditions. Reerve components of both the Navy and Marine Corps re covered in the allowance lists and allowances of mmunition are based on the number of men in each.

Records, Reports, and Medals

Strict accounting of all ammunition used in the servces has to be maintained. As a result, periodic reports elated to quantity, serviceability, inventories, expendiures, etc. are mandatory. Reports are made by letter nd on standard forms provided for that purpose. They re directed to the Chief of Naval Operations, the hief of the Bureau of Ordnance, the Chief of Naval ersonnel, and others concerned.

SMALL ARMS RECORDS.—The records used for small rms ranges are concerned with information necessary o be recorded at the firing lines and in the pit (butts). he PIT RECORD is completed on Small Arms Sheet 2, PNAV–3573–2 (Rev. 1–54). (See fig. 9–3.) The chief it officer, during a record practice, records the scores n ink or indelible pencil on the above form. This rough opy is known as the pit record and is kept by relays. ndividual names are not recorded here, but relays and arget numbers serve to identify the individuals later. ards known as PIT CARDS are completed one for each arget for each string of shots. The pit officer collects hese cards and transfers the information from each o his pit record.

FIRING LINE RECORDS are also kept on Small Arms Sheet 2. (See fig. 9–3.) During record practices a rough copy of these reports is kept by the officer in harge of the firing lines in ink or indelible pencil. On his record each firer is recorded by relay and target umber and, in addition, by name. The officer in charge f the firing lines records data on these records as it omes from the score boards in a prescribed manner. Score boards (usually blackboards)are portable and are placed at the firing line being used, one for each target. Scores on the firing line record are always checked

SMALL ARMS—SHEET 2
OPNAV-3573-2 (Rev 1-54)

Report of Scores

(See instructions on reverse of this sheet)

Ship or station

Division or activity ----------------------------

Place ----------------------------

Date of firing ----------------------------, 19--

Weapon fired ----------------------------

Course fired ----------------------------

Target No.	Full name	File or service No.	Rank or rate	Branch of service	Scores						Qualification
										Total	

I certify that the above record practice was conducted in accordance with regulations.

Name
------------------------, *U. S. Navy.*
Rank *Chief Pit Officer.*

Name
------------------------, *U. S. Navy.*
Rank *Officer in Charge of Firing Line.*

against the pit records before any announcement is made concerning qualification of the firer. Of course, these figures have to be checked also before a smooth copy of the firing line record is made. In order for the pit records to be correctly kept, it is necessary to keep the different relays firing in the same order until completion of firing.

SMALL ARMS REPORTS.—Each command, ship, or shore station conducting small arms firing submits an annual report at the completion of the small arm year. This report is forwarded to the Chief of Naval Operations (OP–34) and consists of a completed Small Arms Sheet 1, OPNAV 3573–1 (June 1953) containing data on all record firings for the year. (See fig. 9–4.) This form is forwarded as an enclosure to a covering letter which comments on the methods of training, items of interest, and any recommendations connected with small arms firing; and reports of Navy small arms practices fired by Marine detachments aboard ship. This report will be submitted as part of the ship's report and a copy furnished to the Commandant of the Marine Corps.

A REPORT OF RIFLE AND PISTOL MATCHES is made immediately upon completion of a Navy or fleet rifle and pistol competition. The original of this letter report goes to the Chief of Naval Personnel and a copy to the Chief of Naval Operations. This report is made by the officer ordering the competition and is a letter report covering the date and place of each match; name, unit, or organization of winning team and the aggregate score; name, rank or rate and aggregate score of each team member of the winning or placing team in team matches, and the same for each individual medal winner in individual matches; name, unit or station of other competing teams, their aggregate scores and standing in team matches; and requests for team and place badges, comments on the conduct of the competition, and items of interest regarding small arms training and team organization.

Entries in the enlisted SERVICE RECORDS concerning

SMALL ARMS—SHEET 1
OPNAV-3573-1 (June 1953)

Ship or station

--------------------, 19----

From: Commanding Officer.
To: Chief of Naval Operations (Op 34).
Subject: Annual report of small-arms practice.

1. The following are the results attained by this command for the small-arms year ending June 30, 19-----.

Table of officers and men who fired, with qualifications

Number firing (A)	Course	Number qualified as (B)	Percent: (B)÷(A)
----------	Course A ----------	Rifle marksman ----------	----------
		Unqualified ----------	----------
----------	Course B ----------	Rifle marksman ----------	----------
		Rifle sharpshooter ----------	----------
		Rifle expert ----------	----------
		Unqualified ----------	----------
----------	Course C ----------	Carbine marksman ----------	----------
		Carbine sharpshooter ----------	----------
		Carbine expert ----------	----------
		Unqualified ----------	----------
----------	Course D ----------	Pistol marksman ----------	----------
		Unqualified ----------	----------

		Pistol marksman	
	Course E	Pistol sharpshooter	
		Pistol expert	
		Unqualified	
		Revolver marksman	
	Course F	Revolver sharpshooter	
		Revolver expert	
		Unqualified	
	Course G	Submachine gun	
	Course H	Ground machine gun	
	Course I	Automatic rifle	

Landing party or NEGDF complement ---------------------------- officers ---------------------------- enlisted.

Authorized allowance ---------------------------- officers ---------------------------- enlisted.

--------------------------------------, *Commanding.*
Signature

NOTE.—In Courses G, H, and I, use qualifying score to determine percentage qualified.

Figure 9—4.—Small Arms Sheet 1.

small arms firing are made by commanding officers upon receipt of Small Arms Sheet 2 (Report of Scores). Page 5 of the enlisted man's service record is the Gunnery Record, NavPers–601 (Rev. 3–50). On this page are sequentially entered all data concerning an individual's gunnery experiences. Small arms practices, qualifications, and awards are entered hereon. Even if the man fails to qualify after preparatory training in small arms, an entry to this effect must be made in the gunnery record as this fact affects his eligibility to fire again for a preset time. All information concerning an officer's small arms qualifications is forwarded to the Chief of Naval Personnel for inclusion in his file jacket.

REPORT OF SCORES is made on Small Arms Sheet 2. Immediately after each record practice, the officer in charge of the firing line completes this form and submits a copy to each commanding officer concerned with the practice. These records have to be certified by both the pit officer and the officer in charge of the firing line. The smooth copy of this report is compiled from data contained on the pit record and the firing line record. In case of disagreement between these two sources of information, the PIT RECORD WILL CONTROL.

COMPETITIONS AND MEDALS.—There are numerous competitions held throughout the services. Navy personnel and Marine personnel are eligible to compete in matches other than their own under specified circumstances. Medals are awarded for successful qualification in several types of small arms firing.

All commanders are encouraged to conduct rifle and pistol competitions to the fullest extent that time, facilities, and ammunition allowances will permit. The major objectives of competitive firing are to extend the scope of regular small arms training, stimulate interest in small arms firing, and to select and develop both individuals and teams to represent the Navy in national and international competitions. Each separate command or unit ashore or afloat should, to the limits possible, organize and train teams for pistol, rifle, revolver, and arbine firing matches. The small arms used are standrd Navy ordnance pieces. However, it is permissible o use specially serviced pieces for match firing. The ureau of Ordnance will furnish specially serviced arms or special matches. Specially serviced arms have been smoothed up" in operation. There have been no maor changes to these pieces, nor have the trigger pulls een reduced below specified minimums.

Ammunition allowances and the courses to be fired n competitions are set and fixed on an annual basis. n areas in which insufficient personnel are available to orm teams, individuals may still participate in trainng and match shooting. Each commander is authorized o train personnel from which to select team members or one team. Commanders are further authorized to rrange competitions between his team and local cometition, such as other armed services, reserve compoents, law enforcement agencies, and civilian rifle and istol clubs in the vicinity. Type commanders, district r river command commandants, or senior officer presnt of ships operating in close proximity may conduct mall arms competitions matching teams in each weapons lass from the units afloat and/or activities ashore. The ommander-in-chief of each fleet is authorized to conuct an annual fleet competition These shall be team nd individual matches with the pistol and rifle. The hief of Naval Personnel is authorized to conduct an nnual United States Navy competition which matches ndividuals and teams representing the various fleets and hore activities These competitions are for rifle and istol firing. Appropriate trophies and other awards re given winners of each of these competitions. The leet commanders award fleet trophies, and the Chief of aval Personnel awards the United States Navy trohies.

PLACE BADGES are awarded by the fleet commanders o individuals for pistol and rifle excellence. These adges are provided and engraved by the Chief of Naval

Personnel who also sets the standards for the matches and the badges.

In order to qualify for the designation of DISTINGUISHED MARKSMAN and the award of a Navy Distinguished Marksman Badge, the individual must have received three major rifle marksmanship awards previously. Specified conditions and limitations exist which delineate the manner in which these three awards must have been earned when considering them as fulfilling the requirements for the Badge. Qualification for the award of a Navy Distinguished Pistol Shot Badge closely follow those for the distinguished marksman award.

An EXPERT RIFLE MEDAL will be awarded to each OFFICER AND ENLISTED MAN who qualifies as expert rifleman by firing of appropriate rifle or carbine course and attains the proficiency set forth by regulation. Commanding officers submit the requests for these medals as they are earned. Small Arms Sheet 2 is completed in each instance and forwarded to the Chief of Naval Personnel who issues the medal.

An EXPERT PISTOL SHOT MEDAL will be awarded to each officer and enlisted man who qualifies as expert pistol shot by firing the appropriate .45 caliber automatic or .38 revolver course and attains the proficiency required. The medals are awarded and issued the same as those for the expert rifleman award.

Qualification as an expert rifleman or expert pistol shot terminates at the end of four years. If the person who has earned one of these awards fails to requalify during the four-year period, he must cease to wear the ribbon significant of this ward unless and until he does requalify. The medal for these awards may be retained for the periods of nonqualification, but not worn. Only one such medal is issued to an individual. If it is lost or damaged so that it is unfit for wear through no fault of the owner, it will be replaced without cost.

If a man fails to qualify for expert, he may still qualify as a SHARPSHOOTER OF a MARKSMAN. While no medals are issued for these qualifications, an entry is made on page 5 of the service record to the effect that the person has so qualified.

Safety Precautions

No attempt will be made in this chapter to give in detail the many safety precautions associated with the correct handling, operation, field stripping, reassembling, and firing of each type of small arm used in the Navy. Pertinent instructions and safety precautions are published for each type of arm and may be procured in quantity if desired. There are, however, certain basic precautions concerning small arms utilization and range procedures which should be stressed repeatedly at all small arms facilities, both on the range and in the classroom. These precautions should be conspicuously displayed at the range as well as in the classroom. They should become a matter of habit for personnel assigned to and undergoing training at the range.

The general safety precautions and regulations to be applied to the utilization of small arms are as follows:

1. Treat every weapon with the respect due a completely loaded weapon.
2. Never point a weapon at anyone you do not intend to kill.
3. No weapon will be loaded except at the firing point.
4. During and after loading, the weapon will be kept aimed in the safest direction until pointed at the target for firing.
5. On leaving the firing line, open the breech and leave it open.
6. Never leave a loaded weapon or one with rounds in the magazine where it may be picked up by others.
7. Immediately upon picking up a weapon and pointing it in a safe direction, make sure by personal inspection that it is not loaded.
8. Do not turn around on the firing line at any time with a weapon in hand.
9. Do not consider a weapon unloaded and safe after

having removed the magazine only. Always examine the breech for a round in the chamber after removing the magazine.

10. Ascertain that the bore and action of a weapon are not obstructed in any manner prior to loading and firing.

11. Never leave the firing line to mark targets until specifically told to do so by competent authority.

12. Any and all misfires should be treated as hangfires. In no event should the breech be opened sooner than 10 seconds after the last attempt to fire the round is made.

13. Never become hurried when involved in handling and firing weapons. Strive to be relaxed but alert at all times.

14. Strict discipline with regard to distractions, such as loud talking and skylarking, will be observed throughout the range, and all personnel not actively engaged in some phase of range work or actually firing will be ordered to leave the premises.

QUIZ

1. The primary aim(s) of small arms range training is
   a. safety
   b. accuracy
   c. tactical employment
   d. all of the above

2. Military small arms range facilities may be used by civilian organizations providing they do not
   a. interfere with military training
   b. incur government expense during usage
   c. leave the range unpoliced upon usage
   d. all of the above

3. Twenty percent of all shore-based personnel are required to qualify in small arms to
   a. stand watches
   b. perform in landing parties
   c. perform in Naval Emergency Ground Defense Forces
   d. all of the above

4. All Navy small arms ranges are closely checked for
   a. remote location
   b. closeness to ammunition dumps
   c. physical layout and adaptability
   d. distance from magazines

5. Petty officers ordered to duty with the Marine Corps for intensified small arms training are returned to the Navy to
   a. become members of pistol teams
   b. instruct other naval personnel
   c. qualify in advancement in rating
   d. qualify as an Expert Pistolman

6. After a small arms range facility has been constructed and is ready for use, it is manned by
   a. personnel assigned by the commanding officer of station
   b. petty officers only
   c. Marine Corps personnel only
   d. personnel assigned by the gunnery officer

7. Navy pistol ranges are standardized only to the extent tha they incorporate
   - a. 50, 25, and 15 yard courses
   - b. 75, 50, and 25 yard courses
   - c. 25, 15, and 10 yard courses
   - d. 35, 25, and 15 yard courses

8. To qualify as a pistol MARKSMAN, the D course is fired fro 15 and 25 yards with the
   - a. cal. .22, cal. .38, and cal. 45
   - b. cal. .22 only
   - c. cal. .38 only
   - d. cal. .45 only

9. The M1 rifle is fired normally for MARKSMAN and EXPERT o ranges of
   - a. 200, 300, and 500 yards
   - b. 100, 300, and 500 yards
   - c. 100, 200, and 500 yards
   - d. 200, 400, and 500 yards

10. To qualify as a rifle EXPERT, a rifleman must score
    - a. 350 out of a possible 400
    - b. 300 out of a possible 400
    - c. 292 out of a possible 340
    - d. 306 out of a possible 340

11. The ammunition for automatic weapons instruction practic must come from
    - a. monthly ammunition allowances
    - b. ammunition available at range
    - c. ammunition allowances available
    - d. ammunition unsuitable for record firing

12. Maintenance on all types of ranges varies only with the
    - a. number of personnel using range
    - b. size of range
    - c. location of range
    - d. types of ranges

13. In the construction of a small arms range, safety is a prim consideration. Therefore,
    - a. safety features have to be constructed
    - b. all natural features must be utilized to advantage
    - c. signs, fences, and patrols must be used
    - d. all of above

4. Two general types of small arms targets are used in the Navy. They are
   a. small bore and those used for all other small arms
   b. slow and rapid fire
   c. 25- and 50-yard target
   d. practice and record firing

5. The National Rifle Association of America is supported in part by
   a. Congress
   b. House of Representatives (State)
   c. Senate (State)
   d. N. R. A. members

6. Butts are constructed by the piling of earth and
   a. stone
   b. timbers
   c. concrete
   d. earth only

7. Target supports are constructed of
   a. pipe
   b. angle iron
   c. wood
   d. cardboard

8. The first exercise in learning the firing of small arms is
   a. proper sight alignment
   b. trigger squeeze
   c. stance
   d. breathing

9. The maximum continued practice of dry firing in minutes at any one time is
   a. 15
   b. 30
   c. 45
   d. 60

0. The minimum continued practice time before the trainee's actual firing is
   a. 1 day
   b. 2 days
   c. 1 week
   d. 2 weeks

When instructing a man in firing techniques, it is more difficult to teach the man who
  a. has never fired
  b. has acquired bad shooting habits from self instructing
  c. is left handed
  d. is nervous

22. Group instructors should be
  a. officer personnel
  b. chief petty officers
  c. small arms specialists
  d. petty officers

23. The officer in charge of the range is responsible to the
  a. Gunnery Officer
  b. First Lieutenant
  c. Security Officer
  d. Commanding Officer

24. Responsibility for safety and proper conduct of firing exercise lies with
  a. all hands concerned
  b. Safety Officer
  c. Executive Officer
  d. Commanding Officer

CHAPTER 10

AMMUNITION HANDLING AND STOWAGE METHODS

GENERAL CONSIDERATIONS

"Ammunition" means to the Navy a great variety of ordnance materials. More than one would at first suspect. Also, the Navy is specific as to which materials and items constitute "ammunition." These materials and items are: All components and any and all explosives in any case or contrivance prepared to form a charge, complete round, or cartridge for small arms, rifle, gun, cannon, or for any other weapon, or for explosive actuated device, impulse device, torpedo warhead, mine, bomb, depth charge, fuze detonator, projectile, rocket, or guided missile; all solid propellants; hypergolic liquid (capable of spontaneous combustion on contact) propellant systems; and all other hazardous materials applied to ordnance uses and/or requiring surveillance for reasons of explosive safety; JATO boosters, sustainers, military pyrotechnics, and offensive type chemical warfare materials. In discussing ammunition handling and stowage, only those items proprietary to aviation will be discussed.

Responsibilities

Basic responsibility for all ammunition (as defined above) is vested in the Bureau of Ordnance. Such responsibility includes procurement, supply, and accounting. However, cognizance of ammunition may be assigned to other bureaus and to the Marine Corps in specific instances. Commanding officers of naval ammunition depots, naval magazines, and other like activities under the cognizance of the Bureau of Ordnance are DIRECTLY responsible to the Chief of the Bureau of Ordnance. Further delegation of responsibility and authority for handling and stowage of all types of ammunition is made down to the individual activity ashore and afloat. Within the individual activity responsibility and authority for handling and stowage of ammunition is delegated by the commanding officer down the chain of command, however set up, to eventually become a matter within the purview of the leading petty officers.

Responsibilities for handling and stowing ammunition are clearly outlined in great detail in publications such as the *Bureau of Ordnance Manual, Bureau of Ordnance Instructions, the Navy Regulations,* OP4 *Ammunition, Instructions for the Naval Service Afloat,* OP5 *Ammunition, Instructions for the Naval Service Ashore,* OPNAV 34P1 *United States Navy Safety Precautions,* and others prepared by district commandants, fleet commanders, and even duly authorized ones prepared at local levels. They are all regulatory along certain basic lines which deal with supply, procurement, accounting, allowances, expenditures, recordkeeping, safety in handling and stowage, maintenance, inspection, and surveillance.

Organization and Personnel

The leading aviation ordnance petty officer may be considered a mainstay in the organization for handling and stowing ammunition of all types. It is under authority and responsibility delegated to him that the bulk of the work incident to handling and stowing ammunition is performed. The organization of all personnel engaged in and the methods for handling and stowing of ammunition are not separate and detached entities. They are more the organization of the Navy itself. In other words, they are merely a part of the overall organizational framework of the Navy. The delegation of authority and responsibility down the line from the commanders to the leading petty officers assures an organization capable of handling and stowing ammunition with maximum effectiveness and safety. A factor in this is the control which prevails at all points along the chain by those in authority. Adequate personnel to accomplish the work at hand is assured by the manner in which the organization is established.

Receipt and Shipment of Ammunition

Handling of ammunition whether in receipt, shipment, transshipment, or other evolution in which ammunition is actually moved, involves great potential dangers. Therefore, SAFETY IS THE PRIME CONSIDERATION N ANY SUCH MOVEMENT.

Before taking aboard ammunition received in any conveyance, an inspection shall be made of the condition and security and the contents checked against the invoiced quantities. A report of any shortage, error, defect, or discrepancy shall be made. Ship and shore stations receiving ammunition in leaky containers or ammunition showing evidences of rough or improper treatment shall investigate the circumstances immediately and submit a complete report to the Bureau of Ordnance.

A copy of the completed invoice shall accompany every delivery or shipment of ammunition. When explosives and ammunition are shipped, the material will be carefully identified on BILLS OF LADING or SHIPPING TICKET by shipping name, caliber, mark and model number manufacturer's name or initials, lot number, and such other information as may be required by other instrucions.

OP 2165 contains complete instructions for transportation of ammunition and explosives.

When shipment of ammunition is made which must cross state boundaries, the regulations of the Interstate Commerce Commission must be met with few exceptions. These regulations are spelled out in several publications issued by the Commission. The military is permitted to make shipments which do not comply strictly with the Commission's regulations. However, such shipments are held to an absolute minimum and every possible effort is made to actually be in compliance with the Commission's regulations in each such shipment. Prior to packaging and packing, all ammunition shall be laid out, counted, and checked. A PACKING SLIP showing the date and names of the packer and checker shall be placed in each case. Heavy articles will be separated from light ones and not packaged or packed together. Articles of different freight classifications should not be packed together as all articles in the same case will take the classification of the article classified the highest.

When a shipment of ammunition is received, by any mode of transportation, a working party of sufficient size will be organized to properly handle the contents of the shipment. If, after commencing the job of handling the ammunition, it is seen that all of the personnel in the working party are not needed to effectively carry on the work, all extraneous members of the party will be promptly retired. This safety precaution will obtain at any and all times ammunition is being handled—only those actually needed should be allowed to remain in the area.

Handling Equipment

Ammunition handling equipment makes it possible to move heavy loads with ease and safety. However, safety is to a large extent dependent on the proper qualification of the operators and a continuing inspection and preventive maintenance program for all the equipment. Hoists, electric fork lift trucks, skids, bomb trucks, slings, pallets, cargo nets, and all other handling equipment are subject to failure in use. In order to prevent failures and resulting accidents, this equipment has to be periodically inspected and discrepancies rectified. Operators will constantly have to be checked to insure that they are complying with all of the safety regulations concerning operation of their equipment and are adhering to established handling methods.

There are specialized tools for use on and around ammunition. These tools are constructed from nonferrous metals so that they will in no manner cause sparks while being used or if accidentally struck or dropped. Pliers, wrenches, hammers, mauls, drifts, sparkproof flashlights, safety lamps, and others are examples of the special safety tools. It will be found that these tools, being made from nonferrous metals, do not stand up under severe usage as do their steel counterparts. Therefore, care must be exercised in their use if they are to last for any length of time.

Records and Reports

Commanding officers of vessels and shore activities are required to make reports of all ammunition and ammunition details within their commands. These records shall show all receipts, transfers, expenditures, and quantities on hand. Also included in these records will be complete ammunition identification data, including lot numbers and mark and modification numbers of all ammunition and ammunition components. Commands held accountable for ammunition are responsible for submitting reports regarding inventories, performance, and similar items in strict accordance with *Navy Regulations* and *Bureau of Ordnance Instructions,* or other competent authority.

Daily magazine temperature reports are made by each command accountable for ammunition. These reports are compiled from the temperature readings taken at a specified time each day in each magazine, dump, or ready locker under the cognizance of the commanding officer of the activity. Copies of these reports are sent to the Bureau of Ordnance as per instructions. Temperature entries are made in rough and smooth magazine logs both ashore and afloat.

Operating and service squadrons are required to submit annually to the station at which they are based an

ON HAND report. This report contains information as to the inventories of aviation ordnance equipment on hand. The air stations receiving these reports will consolidate them with their own records and forward the consolidated reports to their respective Naval Air Base Commands. It is the duty of the Naval Air Base Commands to consolidate all of these reports and forward one master copy to the Bureau of Ordnance annually. In making the inventory reports, the squadrons will not include their aircraft equipment.

There are numerous other reports that have to be made periodically concerning ammunition. Some of these reports are the available storage space at an activity, lost or erratic torpedoes, performance of ammunition used, performance of ordnance equipment, pyrotechnics performance, and others. Excellent references for types of reports and their reporting dates as well as the activities who submit them are the various consolidated lists of recurring reports.

The records and reports common to the AMMUNITION STOCK RECORDING SYSTEM will be covered later in this chapter.

ORGANIZATION AND PROCEDURES AFLOAT

Personnel and Organization

When ammunition is received by a ship, at sea or alongside a dock, certain measures have to be taken immediately to safely bring aboard and properly stow these munitions. The Commanding Officer is informed of the shipment's arrival and through the Executive Officer and the Operations Officer he will prepare the ship for receiving the ammunition. The Operations Officer, the Executive Officer, and the Gunnery Officer working together will organize the necessary ammunition handling parties and break out the necessary handling equipment with which to load the ammunition aboard and stow it away.

Once the ammunition shipment is received and the handling parties have commenced unloading, work is not interrupted until the transfer is completed. This means that the handling parties will have to be relieved periodically in rotation for messing and for off-duty periods. The handling parties are composed of personnel from most of the departments of the ship with certain rates and ratings selected for supervisory duties from each department. The ship's company Chief Gunner will most likely be immediately in charge of loading operations and have under himself the Chief Gunner from the Air Department and various leading petty officers from the other departments. A large ammunition shipment being loaded aboard ship affords most of the aspects of an "all-hands evolution."

Ammunition handling equipment will be manned by qualified operators in unloading the boxcars, lighters, trucks, or other conveyances in which the ammunition is received. Ammunition conveyors, skids, trucks, fork lifts, and other equipment will be placed and utilized to the greatest advantage in expediting the handling of the ammunition. Safety personnel (guards) are placed at strategic locations to enforce safety regulations pertinent to ammunition handling. Ammunition that is accidentally dropped, bumped, or otherwise jarred is set aside for disposition.

Organization for the handling of ammunition has to be carefully worked out and much thought and planning given to all details no matter how small and insignificant some may seem on the surface. Due to the incipient hazards connected with handling ammunition, no factor may be overlooked in setting up the organization and carrying out the work. Personnel selected for crews have to be qualified for the particular job they are to undertake. Personnel in supervisory positions especially have to know all the details of their particular jobs and how to coordinate their work with other supervisors. The petty officer in immediate charge of handling operations should recognize the fact that there are more personnel than actually needed for the handling operations and remove those in excess from the working areas.

The Commanding Officer is responsible for all loading and handling operations. In view of this fact he makes certain that the officers and crew are instructed in the safety orders and all requirements of care, handling, stowage, and examination of explosives. He assures that all proper, necessary, and prescribed precautions are taken relative to care, handling, and stowage of ammunition aboard ship.

The Gunnery Officer makes it his responsibility to instruct the officers and crew in the safety orders and all regulations regarding the care, stowage, handling, and examination of ammunition. He also sees to it that all personnel are drilled and instructed in the safety orders for the spaces aboard ship where ammunition is stowed.

No personnel shall be allowed to inspect, prepare, adjust, or otherwise work with live ammunition until they thoroughly understand their duties and the hazards involved. Inexperienced personnel are not allowed to work alone, but must be under the direct and continual supervision of skilled and experienced personnel. Those engaged in this work must be known to be careful, reliable, mentally sound, and physically fit.

Receipt and Deliveries

Safety precautions relative to receipt and delivery of ammunition will be found in a later section of this chapter.

In order for the leading petty officers to better understand the factors involved in the receipt and delivery of ammunition aboard ship, it will be helpful to briefly outline the duties and responsibilities of the departments and department heads concerned with these evolutions.

THE GUNNERY OFFICER.—The responsibilities of the heads of the Air Department, the Operations Department, the Executive Officer, and the Commanding Officer will not be considered here. The Gunnery Officer has as his assistants, when concerned with receipt and deivery of ammunition, the Ordnance Officer, the Armory and Magazine Officer, the ship's Warrant Gunner, the Chief Gunners Mate, and the leading petty officers from various departments. With these personnel under his supervision he is able to carry out his duties with regard o receiving and delivering ammunition with the maxmum effectiveness. These are to supervise procurement, handling, stowage, accountability, and issue of convenional aircraft ammunition, special weapons, and pyroechnics in accordance with existing directives; conduct urveillance tests of ammunition and pyrotechnics; conduct periodic inspections of magazines; maintain the physical integrity and security of the magazines and eady service storage spaces including the control of the assigned magazine keys; supervise and direct the stowage, care, and maintenance of torpedoes and components of missiles which are explosive, both airborne and air-o-ground; and assume such other responsibilities as are assigned.

THE ORDNANCE OFFICER.—The duties of this officer with respect to receipt and delivery of ammunition are: Direct the procurement, handling, stowage, maintenance, nd uses of ammunition and the preparation of reports nd records pertaining thereto; and such other duties s may be assigned.

THE ARMORY AND MAGAZINES OFFICER.—This officer, nder the Ordnance Officer, has duties with regard to eceiving and delivering ammunition as follows: Mainain accurate records of all ammunition, keeping a current alance of expenditures and receipts of all types, and rocure ammunition as necessary to conform with the hip's allowance of ammunition; exercise overall superision of ammunition handling parties and personally nstruct all key personnel in pertinent safety precautions RIOR to conduct of such evolutions; supervise the opration and maintenance of assigned ammunition hoists; nspect the magazines, magazine logs, ammunition logs, nd surveillance logs daily to insure that temperatures required are maintained and monthly magazine sprinkler system tests are properly conducted. The Armory and Magazines Officer shall further be responsible for posting and enforcement of applicable safety precautions, operating instructions, and casualty procedures in assigned spaces; prepare instructions for, train, and post the magazine security patrol and the armory watches; maintain the custody of the magazine keys and personally turn them over to the Gunnery Officer when leaving the ship; insure the preparation and submission of ammunition records and reports to the Ordnance Officer as required; be responsible for procurement, accounting, testing, maintenance, and issue of mines and torpedoes; and administer the operation and maintenance of the torpedo shop.

THE SHIP'S GUNNER.—This officer is responsible for: Procurement, accounting, stowage, and care of the ship's ammunition (under direction of the Armory and Magazines Officer) exclusive of that belonging to the Air Department; maintaining accurate records of all ammunition, keeping a current balance of expenditures and receipts of all types; procuring ammunition (subject to approval by the Armory and Magazines Officer) to insure conformance with the ship's ammunition allowance; personally supervise all ammunition handling parties; personally inspect the magazines, magazine logs, ammunition logs, and surveillance test logs as required; and train and schedule watchstanders for the magazine security patrol and armory watch.

The Ship's Gunner shall further be responsible for issuing, under his personal supervision, all ammunition to the Air Department; maintaining custody of the magazine keys assigned by the Armory and Magazines Officer; assisting in the preparation and submission of ammunition records and reports; initiating requisitions for ammunition for the approval of the Armory and Magazines Officer; and performing such other duties as may be assigned.

All leading petty officers of the Gunnery Department work directly under the Ship's Gunner in receiving and delivering ammunition. Personnel supervised by the eading petty officer report directly to these petty officers on any and all matters pertaining to ammunition handling. It is the duty of the first class and chief petty officers to be with the men under them to insure that all safety precautions are carefully and consistently carried out. They should be alert to spot any and all ack of proper training among the men under them and take immediate steps to eliminate the cause of potential danger either by properly instructing the offender or causing his removal from the ammunition handling party if it is felt that the offender may again repeat the dangerous practice. One mistake is too many in working with ammunition.

The Aviation Ordnance Officer, who functions under the Air Department, has as his assistants when concerned with the receipt and delivery of ammunition, the Aviation Ordnance Gunner, and the leading petty officers of the Air Department. At times, the Aviation Ordnance Gunner will be coordinating the work with leading petty officers from other departments as well as from his department.

THE AVIATION ORDNANCE OFFICER.—This officer shall perform the following duties with regard to receipt and deliver of ammunition: Direct the stowage of all ready airborne complex weapons, missiles, and related equipments including ground-to-air missiles, except for their explosive components; maintain liaison with the Gunnery Department on matters concerning allowances and stowage of aviation munitions and explosive components of the complex weapons; provide armories and an aviation ordnance issue room for use by squadron ordnance personnel; maintain liaison with the Gunnery Department in breaking out required aviation conventional and complex munitions; insure that operating procedures and safety precautions are promulgated and strictly observed;

organize and instruct selected personnel in the loading and handling procedures for special weapons; obtain reports of the quantities of ammunition on hand from the Aviation Ordnance Gunner, and direct the replenishment of the ship's aviation ordnance and related equipment; keep informed of the condition of ordnance elevators while insuring the safe custody and constant operational readiness of this equipment; initiate and forward to the Assistant Air Officer requisitions for replenishment of weapons, equipment, supplies, and materials, and perform such other duties as may be assigned.

THE AVIATION ORDNANCE GUNNER.—The Aviation Ordnance Gunner will perform the following duties: Supervise the stowage and maintenance of aviation ordnance materials under the cognizance of the Air Department, including bomb cranes, skids, and trucks; insure security and maintenance of ready service magazines, workshops, and assembly areas under cognizance of the Air Department; supervise assembly of munitions and complex weapons, and the delivery of munitions to the flight deck and hangar deck via the bomb and torpedo elevators; supervise the transfer of special weapons to the flight deck via bomb elevators; insure the strict observance of all safety procedures and regulations relative to handling ordnance materials; assist the Gunnery Department in loading and off-loading all ship's ammunition by operating bomb elevators, supplying bomb skids, and providing personnel; and performing other duties as assigned. The above duties are in connection with receipt and delivery of ammunition.

All leading petty officers of the Air Department work directly under the Aviation Ordnance Gunner in the receipt and delivery of ammunition. The men supervised by the leading petty officers report directly to these petty officers on any and all matters concerning handling of ammunition. Here again, it is the duty of the leading petty officers to be with the men under their supervision and insure that all safety precautions and

ocedures are strictly observed—observed to the letter.
hey should make it known to the men under them that
NYONE observing a dangerous practice or a dangerous
tuation while handling ammunition should immediately
ke the necessary steps to correct the practice or situa-
on and then make a full report to their immediate
perior. Leading petty officers should screen the men
der their supervision who constitute the membership
ammunition handling parties and insure that all are
able, alert mentally, and physically capable of per-
rming their duties. If their makeup is otherwise,
ey should be transferred to other less dangerous duties.
avoid the likelihood of dangerous situations arising,
e leading petty officers have to constantly bring all the
tails of safety regulations, procedures, and precau-
ons to their men. They cannot afford to relax this
pe of instructional work at all if they are to prevent
stly accidents.

The first class and chief petty officer have a heavy
sponsibility in the handling of ammunition to insure
at all work is completed effectively and in a minimum
time with the GREATEST POSSIBLE SAFETY to all hands.
ese petty officers have all the authority necessary to
eate a safe and efficient handling team for receiving
delivering ammunition. Authority alone, however,
ill not suffice to afford safe and effective results. A
ose working relationship with the men supervised and
constant instructional program are necessary to as-
re the results desired and demanded by those in
thority.

Return of Munitions

Ammunition as a category of material is fairly stable.
owever, it will become unserviceable at times due to
veral reasons. Whenever it does become unserviceable,
it is suspected that some damage may have occurred
it, RETURN OR DISPOSAL HAS TO BE INSTITUTED. Dam-
ges to ammunition may result from flooding of mag-

azines; excessive temperatures within magazines; dropping, bumping, or otherwise subjecting it to rough handling; improper stowage (JATO units); exposure to direct sunlight for excessive periods; general deterioration due to age; and many other causes. Damaged or unserviceable ammunition shall be marked or tagged to show the type of damage or reason for unserviceability and the name of the ship.

The commanding officer of the ship is responsible for the care, surveillance, testing, inspection, and overhau of ammunition. He shall arrange for and request authority from the Bureau of Ordnance for the overhau of ammunition at an ammunition depot during a regular navy yard overhaul of the ship. During such overhau period, the commanding officer, when requesting authority to turn in his ammunition for temporary storage should also request the commanding officer of the ammunition depot to have his service allowance of ammunition inspected. This inspection determines the requirements for overhaul and replacement and further provides the data for a report on the condition to the Bureau of Ordnance. The commanding officer of a ship ordinarily takes advantage of the first opportunity for periodic ammunition overhaul because unexpected changes to schedules and duties of the ship may force him to retain some ammunition on board for periods longer than the maximum time allowed.

In general, the return of ammunition requires specific arrangements to be made in advance of the actual transfer in order that proper authority may be obtained, shipping and storage provisions made, and the necessary ammunition handling parties organized. Safety in handling damaged and unserviceable ammunition, if anything, is more important than in handling serviceable ammunition. DAMAGED AMMUNITION IS GENERALLY MORE DANGEROUS THAN THAT WHICH IS SERVICEABLE.

The status of various ammunition requires descriptive nomenclature to indicate the degree of serviceability of e ammunition. Descriptive terms have been assigned designate the various degrees and are as follows:

SERVICEABLE.—Ammunition suitable for unlimited is- e and service use as designed or authorized.

UNSERVICEABLE.—Ammunition not suitable for issue use. This category includes ammunition which has en declared obsolete. However, the Bureau of Ord- nce may authorize the use of certain obsolete ammuni- n for specified purposes.

LIMITED-USE.—Ammunition suitable for specified lim- d use only as authorized by the Bureau of Ordnance. is ammunition may not be used in the unrestricted nner for which it was designed or procured.

SUSPENDED. — Ammunition temporarily withdrawn om issue and/or use by the Bureau of Ordnance, pend- g its reclassification.

All ammunition is classed under one of the above tegories. The results of inspections determine into ich category, or categories, ammunition will be placed. mmanding officers are responsible to the Bureau of dnance for actually placing ammunition into the cate- ries in accordance with the results of the inspection. turn of the ammunition, or other indicated disposition, then made as provided in the current directives.

Inspections and Tests

Inspections, tests, and overhauls are required on many ms related to munitions in addition to those for am- nition itself. All places of stowage require regular pections and tests. Ammunition details, which are essories used in packing, handling, protection, and rveillance of ammunition, require frequent inspections. wever, inspections and tests of ammunition will be cussed here.

Prior to taking ammunition aboard, an inspection ould be made to the condition and security, and the ntents checked against the invoiced quantities. A port shall be made of any shortages, errors, defects, d other discrepancies. Ships receiving ammunition in leaky containers, or ammunition showing evidence rough or improper handling, shall immediately inve tigate the circumstances fully and submit a full repo to the Bureau of Ordnance.

The primary purpose of ammunition inspections is detect deterioration, thereby reducing hazards, to dete and correct defects, and to maintain all ammunition an ammunition components in a safe and serviceable co dition. SURVEILLANCE is close observation, rigid i spection, careful examination, and thorough testing ammunition in the sense used in this chapter. Survei lance applies not only to the ammunition itself, but al to the methods of handling, packing, marking, stowin segregation, and shipping, and to precautions and i structions tending to protect property and personn against hazards inherent in all explosives.

Officers and men charged with the responsibility magazines and the examination of ammunition sh thoroughly familiarize themselves with the practic methods of making such examinations and tests. The will be held responsible for the accuracy of these test the correctness of the official reports concerning the and for the proper instruction of those who actual conduct the tests and inspections. In order for th tests and inspections to be of value and indicative of th condition of the ammunition under surveillance, it i essential that the methods in all details be uniform an those performing the testing perform their duties scrupulously following the prescribed methods. T Bureau of Ordnance records all tests reported from th various sources and keeps careful accounts of the di position and condition of ammunition. Thus, the Bure is enabled to dispose of any and all ammunition whi is unsafe and unserviceable. It may be seen that a curate and timely reporting from the activities an fleets is necessary to assure the correct and prom action by the Bureau of Ordnance.

MAGAZINES.—During the daily inspections of the ma azines, they shall be carefully examined for cleanliness, ventilation, temperature, and the general condition of their contents. Upon entering a magazine a deep breath will be taken to detect the presence of any excessive ether-alcohol fumes. Should such fumes be present, it means that containers are leaking. These will be sought out and removed or replaced immediately. The temperature and the moisture content of the magazine's atmosphere (hydrometric condition) must be constantly watched. Temperatures are read daily and the maximum and minimum figures recorded in the Magazine Temperature Record Book. If one thermometer is allowed for a particular magazine, it shall be placed in the hottest portion of the space. If two are allowed, one shall be placed in the hottest part and the other in the coolest part of the magazine.

A magazine is considered to be in a NORMAL CONDITION when the following set of conditions prevail:

1. Magazine and magazine area are well guarded and protected from fire.
2. Magazine is in good repair, dry, and well ventilated.
3. Interior is neat with contents arranged in orderly piles which do not exceed the prescribed height or quantities.
4. Atmosphere in and around the magazine free of ether-alcohol fumes.
5. Visual testing equipment (violet paper, etc.) indicating correct conditions.
6. Temperature not exceeding 100° F., and no evidence of local heating of smokeless powder containers.
7. Boxes and containers securely closed.
8. Contents of magazine properly identified by lot number and piled with not more than one lot in each pile.
9. Loose rounds, damaged containers, empty containers, paints, oils, rags, dunnage not in use, and other prohibited articles not present in the magazine.
10. Magazine properly placarded inside and out.

11. Only the ammunition types designated for the particular magazine stowed in that magazine.

12. Fire- and lightning-protection equipment maintained in efficient operating condition, and magazines (ashore) properly grounded.

SMOKELESS POWDER.—A complete history must be kept on all smokeless powder on hand. This history contains, among other items of information, the results of all stability tests. Since smokeless powder contains such substances as ether and alcohol, it will not remain stable indefinitely. Stowage conditions in which temperatures are high (above 100° F.) cause this powder to lose stability. The serviceable life of the powder is thereby reduced proportionately. However, loss of stability will not affect the ballistics of the powder and projectile combination if other conditions are normal, unless it has gone so far as to prohibit retaining the powder on board ship.

During manufacture, dried smokeless powder is allowed to take up (before packing at the factory) an amount of moisture corresponding to the average moisture content of the air at the factory. Then, once the powder is packed, it is important that it not be allowed to change in volatile and moisture content thereafter. Containers must be kept airtight and the powder exposed to air as little as possible. Powder is manufactured in lots of so many pounds. After proof and acceptance, a lot or a blend of lots is given an INDEX NUMBER. Index numbers are assigned serially; the first powder manufactured receives the number "one," etc. This indicates that the index number tells nothing more about the powder than its relative age.

There are still other tests and inspections to be made on ammunition magazines. The sprinkler system has to be inspected and tested monthly. There is a specified procedure for this work. Powder samples have to be taken biannually. Magazine flooding controls and valves have to be inspected. Electrical continuity has to be tested within the magazines to insure no dangerous conditions exist in wiring and grounding circuits. Inspection of installed ammunition handling equipment for security, safety, and operation is necessary continually. And many types of surveillance tests and inspection are necessary on the ammunition, its components and details, and the stowage areas in general.

ORGANIZATION AND PROCEDURES ASHORE

Practical Considerations

Air station ordnance officers are confronted with a variety of duties and problems in connection with ammunition handling and stowage. Many contingencies that will arise in their daily work are not specifically covered in official Navy publications. It might be well here to briefly outline some of the practical aspects which are more or less typical of the above situation.

The War Plan Annex of the air station should be studied and reviewed with all units concerned with respect to ammunition and loading of aircraft. The ordnance officer should make provisions for sufficient ammunition, explosives, tools, equipment, and experienced personnel to carry out this plan. This will necessitate frequent inventories and inspections to insure that there is little or no deterioration of ammunition and equipment essential to the plan. He should also schedule rearming drills to bring out deficiencies in this important work and provide competent umpires to cover these drills. The station's Disaster Plan should also be studied with the same things in mind.

It is not only desirable for the station's ordnance officer to maintain close contact with other units connected with or served by his department, it is necessary. He must know and understand the requirements of such units as the FASRons, Fleet Air Material activities, ordnance shops, the supply sections, Marine units, special training activities, and the overhaul and repair activity. Scheduling is another problem for the ordnance officer. He must make sure that he is included in any advance information and planning which would cause him to make requisitions for ammunition, equipment, and personnel to cover training and operational requirements. Deliveries are at times difficult to effect, especially to outlying units. Also, the fields at which the outlying units are based may not have adequate handling facilities for off-loading and rearming. This fact would involve delays in handling and would have to be considered when requisitioning the ammunition.

Air station ordnance departments whose duties include servicing and off-loading ammunition from aircraft carriers MUST remain in constant readiness for this work. No matter what the service required by the carrier, the ordnance department must stand ready to lend effective assistance. Cooperation must be at its highest between the ordnance department and the carrier in order to mutually solve the problems attendant to ammunition handling, stowage, and rearming.

The ordnance department will not maintain its own rolling stock, or handling equipment. The transportation department of the air station has this duty. Therefore arrangements have to be made for preventive maintenance and servicing of the heavy equipment by the transportation department. The light mobile equipment is usually maintained in the ordnance department's garage or shop. The ordnance officer will have to rigidly control the use of his light mobile equipment due to the fact that there is usually a tendency to use this equipment for other than aviation ordnance work.

All safety precautions pertaining to driving and care of the mobile ordnance equipment must be rigidly enforced. Further, regulations concerning the convoys prescribed, red flags, load tiedowns, brake conditions, routing to avoid congested areas, loitering of the drivers, smoking, en route inspections, and other safety items will have to be brought to the attention of all hands regularly and frequently.

Inspections

The inspection afforded shipboard magazines is basically the same as the one for magazines ashore. Those responsible for ammunition ashore will have to be aware of and familiar with all instructions and procedures governing the inspection and maintenance of all ammunition and magazine areas. All magazines should be inspected in detail EVERY DAY. Where this is impossible due to lack of personnel, one or more magazines which are representative of each group or type of magazine must be inspected daily. The results of any and all inspections are recorded in the magazine logs (and rough and smooth OOD logs) over the signature of the person making the inspection.

There are several matters which are not common to shipboard magazines, but which do apply to magazines ashore. One is that a definite firebreak is necessary around all the magazines. It must be of prescribed width and should be kept free of rubbish and other inflammable materials at all times. Another is that all ammunition, explosives and components thereof, must be stowed in the designated and appropriate magazines. They cannot be stowed in buildings used for other purposes. The requirements for normal magazine conditions for magazines ashore are the same as those for aboard ship except that the above two details are added to the conditions for magazines ashore.

Magazine Symbols

Ammunition depots and stations number their magazines in accordance with certain specifications. These numbers are assigned so that inspecting officers and others concerned may at a glance be able to tell how much ammunition can be safely stowed therein, if the magazine is standard, or if it is a nonstandard magazine. Being nonstandard, he will further know that a check is necessary to determine if the amount stowed therein can be safely carried as marked on the magazine.

There are 16 standard types of magazines. The nonstandard magazines have a separate listing with the letters X, Y, and Z appended to their designators. In addition, the standard magazines, which have LESS than the prescribed safety distance from other magazines or inhabited areas, carry the above letters in their designators. Numbers are added to the letters to indicate the location of the magazine. The numbers and letters are painted on a colored background to indicate the nature of the hazard. Each magazine displays a three-group symbol consisting of one number, one or more letters, and a number painted on a colored background. The letter T indicates that the magazine is barricaded. The letter C indicates that the magazine is covered with earth, but that the doors are not barricaded. The colored backgrounds indicate what the buildings are used for and the nature of the hazards, and are as follows:

High explosives—yellow.
Black powder—yellow.
Projectiles—green.
Fixed ammunition—red.
Semifixed cartridges—blue.
Smokeless powder—blue.
Bag charges—blue.
Small arms and pyrotechnics—white.
Chemical ammunition and smokedrums—white and yellow striped.
Fuze and detonator—red and yellow striped.
Inert, combustible—brown.
Inert, noncombustible—black.
Filling house and loading plants—orange.

The letter X on the nonstandard magazine stands for explosive magazine; the letter Y for powder magazines; and the letter Z for projectile magazines. As an example, a magazine designated 7AT28 on a yellow background would convey the following information: Magazine located in Group 7; is of the 80-foot arch barricaded type, located at least 3,150 feet from the boundary, and at least 400 feet from the nearest magazine; is number 28 in that group; and contains high explosives.

Distance from the station boundary or the nearest inhabited building, public railway, or public highway is another of the factors governing magazine designations. All ammunition is grouped for stowage purposes under one of three nonstandard types of hazards (explosives, fire, missile) and is stowed in the appropriate magazine type.

Essential Magazine Data

Certain data concerning magazines are retained by all activities responsible for stowage and handling of ammunition. These data include copies of corrected blueprints, maps, and drawings of all explosive and ammunition stowage, showing the location of all magazines and magazine areas; the type and construction of the magazines; permissible stowage; maximum permissible quantities; actual contents, and distances to inhabited buildings (off naval reservation); and public railways and highways. Each activity supplies to the Bureau of Ordnance periodically corrected charts and other source materials which keep the Bureau current on all stowage problems and facilities at the activity.

Quantity-distance tables, reflecting how much ammunition of what types may be stowed at what distances from specified structures (private and military) and other features, are promulgated by the Bureau of Ordnance. The Bureau bases these tables on data concerning fires and explosions involving naval explosives and ammunition, reports covering a comprehensive series of tests conducted at the Aberdeen Proving Grounds, and from other factual and regulatory sources. These tables, which reflect the quantity-distance specifications, are published in *Ordnance Pamphlet 5*.

Stowage Requirements

As a general rule, stowage facilities ashore (an air station, for example) will include provisions for high explosives, fuzes and detonators, JATO, rockets, small arms ammunition, pyrotechnics, fixed ammunition (20-

mm and larger), inert materials, and smokeless powder. The location and capacity of the magazines will depend on the type of stowage involved. For some explosives, this will be in terms of net pounds. In others it will be based on the use of 70 percent of the gross floor area and a stowage height of 6 feet. For inert storehouses, the same floor area regulation applies, but the height may be greater. The overhead in a standard storehouse is 14 feet. Regulations for the stowage of special weapons are not considered in this chapter.

In order to better illustrate stowage requirements, it might be well to consider a specific example. The requirements for small arms ammunition and/or pyrotechnics will be cited as the example. In general, these types of ammunition, and all others classed as non-mass-detonating, are each stowed in separate arch-type, earth-covered magazines, without a barricade at the door end. The standard size for such a magazine is normally 25 feet by 50 feet. When stowage space for any one type of ammunition is greater than the capacity of this size magazine, additional magazines of the same capacity are required.

Minimum safety distances for small arms ammunition and/or pyrotechnics have been set as follows:

1. Between magazines containing these types—200 feet.
2. Away from high explosive groups—1,900 feet.
3. Away from single high explosive magazine—500 feet.
4. Away from other types of magazines—200 feet.
5. Away from station boundary, inhabited buildings on and off the station, public highways and passenger railways—400 feet.
6. Away from centerline of runways and/or taxiways —750 feet.

An exception to both (1) and (4) above occurs when the "triple-arch" magazine is used. Then the minimum spacing between two adjacent magazines of the same type and between the triple-arch and the other magazines, except high explosives and fuse and detonators, must be 300 feet.

SMALL ARMS AMMUNITION is stowed in separate magazines of the type used for projectile smokeless powder. It is not classified as an explosive hazard, but rather as a fire hazard. High temperatures and dampness are detrimental to this ammunition. It should be stowed by lot number and type, with each pile placarded to show readily all pertinent information. Tracer ammunition should be segregated.

INERT COMPONENTS and NONEXPLOSIVE DETAILS not assembled with ammunition should not be stored in magazines with live ammunition or explosives. They should be stowed in packing boxes and placed on dunnage for protection from dampness.

ROCKET COMPONENTS offer particular hazards in storage. Rocket heads loaded with TNT, Composition B, or HBX are stowed in high explosive magazines. The ballistite loaded motors present only a fire hazard and may be stowed with the fixed ammunition. The rocket fuzes, however, are stowed in the loaded fuze magazines.

PYROTECHNICS should not be stowed with other ammunition. They should be stowed in a dry, well-ventilated place out of the direct sunlight, and should be protected from excessive and variable temperatures. The distance requirements for pyrotechnics are the same as for smokeless powder.

BOMB-TYPE AMMUNITION is usually regarded as the most hazardous type of ammunition because of its tendency to detonate "en masse" if exposed to fire or shrapnel which may enter the magazine where stowed. It has to be stored in a fireproof high explosive magazine on noncombustible dunnage. Arch-type, earth-covered magazines have to be used to stow this type ammunition. The detonators for this type ammunition have to be stowed separately in standard detonator magazines.

Fuzes, tracers, primers, boosters, and detonators not assembled in ammunition should be stored in standard earth-covered detonator or fuze magazines.

Records and Reports

It is mandatory that each activity responsible for stowage and handling ammunition make regular and accurate reports on its ammunition inventories, stowage arrangements and capacities, and other facts to the Bureau of Ordnance. This provides the Bureau with current information on the status and quantity of ammunition for overall accounting and future planning. The Bureau has reduced the number of reports and records to an absolute minimum. Therefore, it is most important that each of the reports and records in current use be employed exactly as directed and completed accurately. Requirements in records and reports depend upon the type of activity, transaction and ammunition, and whether it is afloat or ashore.

There are several NavOrd forms to be used in reporting on ammunition and magazines. A complete listing of all these forms may be found in the *Index of Ordnance Publications,* OP 0.

ORGANIZATION AND PROCEDURES FOR ADVANCE BASES

General Considerations

It is only natural to suppose that in advanced areas there will not be the opportunity to afford ammunition proper stowage—stowage that is in accordance with doctrines established for ammunition depots and shore stations where permanent magazines are available. It is likewise reasonable to suppose that certain measures have to be taken to assure maximum protection to ammunition and personnel alike, even in advanced areas. Certain elementary precautions must be observed in these areas in order to afford an adequate and dependable supply of ammunition. If possible, ammunition to be stowed in advanced areas at bases should at least have the protection of a cleared area. A firebreak 50 feet wide should surround the depot or dump. It is possible that this firebreak will have to be constructed prior to the arrival of the ammunition due to the fact that it has to be burned off for lack of proper tools for clearing purposes. There are other factors involved. It may be highly undesirable to clear vegetation around such a dump because it would spoil the natural camouflage. Smoke resulting from burning-in a firebreak might disclose an otherwise well-hidden position. Those in charge will have to meet the demands of the area and the exigencies of the situation with a great deal of commonsense and a good understanding of the potential dangers inherent in ammunition.

Cover and Protection

When selecting stowage facilities in advanced areas, it is important to take every possible advantage of natural cover for the protection of ammunition from the elements. In so doing, the extreme need for artificial cover is thereby lessened considerably. Ammunition necessarily stowed in the open requires certain precautions be taken in order to insure that it will perform satisfactorily at some subsequent date. It should be raised on dunnage at least 6 inches off the ground and the pile covered with tarpaulin of double thickness. An air space should be left under the tarpaulin, between the tarpaulin and the ammunition, for ventilation. Lacking sufficient tarpaulins to completely cover the ammunition to be stowed, use should be made of vegetation, broken packing cases, burlap bags, or any other materials which may serve the purpose of keeping the direct rays of the sun off and affording as much protection from rain as possible. Suitable trenches should be dug around each pile. This will serve to prevent runoff rainwater from getting underneath the dunnage. The nearest thing approximating a magazine for advance base stowage of ammunition is a revetment or earth barricade. This device serves admirably as a firebreak. It also serves as a shield against shrapnel from enemy bombs and, in case of explosion of the dump itself, serves to deflect and absorb shrapnel which might otherwise set off a nearby dump.

In subtropical and tropical areas it may be impossible to maintain temperatures of the ammunition below the normal limits required. In this event it is imperative to make frequent inspections of the ammunition. Inspecting personnel should carefully test for excessive ether-alcohol fumes from smokeless powder tanks, look for TNT exudate on bombs and mines, and note any deterioration of pyrotechnic materials.

Separate Stowage

So far as possible, various ammunitions should be stowed separately. Further, sufficient distance should be left between adjacent piles of different types to prevent danger to one pile from destruction of another. There should always be sufficient space between piles to provide walkways during inspections. At advanced bases it is highly desirable to stow various calibers and types of ammunition together. However, the entire supply of each type of caliber should never be placed in the same stowage position for obvious reasons. The different types should be distributed between various stowages in such a manner that in no case will the entire supply of any one type or caliber be exposed in the event of fire or other hazard. Therefore, none of these, or any other instructions relative to segregation of ammunition, are to be so interpreted as to preclude the necessary dispersion of ammunition. They shall be held applicable to individual piles in any one magazine or any one of several stowage areas existing at any one activity, not the entire supply at such activity.

Bomb-Type Munitions

Adequate stowage facilities will not be available at most advance bases for bomb-type ammunition, as well as other types. It will nevertheless have to be stockpiled because of its importance to military operations. Since this is the case, it will be necessary to observe certain precautions relative to exposed storage. Back at permanent stowage facilities, fork lift trucks and other related handling equipment make easy work of moving and piling ammunition. At advance bases, procurement of this type equipment will be highly problematical. Bombs will have to be handled by hand most likely and may not be piled due to their weight. Certainly, two high will be all that may be piled by hand and these will probably be only the 100-pounders. Heavier stores will have to be rolled into position in lines which leave enough space between rows in which to walk and work.

It is possible to store general-purpose, fragmentation, armor-piercing, demolition, and other types of high explosive stores in the open, unprotected from the elements, for short periods of time without major impairment of their operational efficiency. There may be mines and other stores containing batteries in the inventory of ammunition at an advance base. This type ammunition CANNOT be exposed to the direct rays of the sun. It must be covered with ANYTHING available to keep the items shaded. It is almost as imperative to cover, from the sun's rays, all incendiary bomb clusters in containers.

Time should be provided or taken during inspection of bomb ammunition at advance bases to tighten all caps, plugs, and other attachments found to be loose. This especially applies to fuze cavities in the bombs. A coating of grease should be placed at the junction of the fuze-hole plug and the bomb body after tightening the plug to keep out moisture. Ammunition received at advance bases will quite often be found with loose fuze-hole plugs; even missing in some instances. Every effort should be made to procure and install these plugs where missing. If this is impossible, then wooden plugs should be cut to fit and installed until the ammunition is expended or standard plugs are obtained, whichever occurs first. All threaded sections of the bombs should be coated with grease. Nose and tail fuzes and suspension lugs will screw in smoothly if grease is used to protect threads from corrosion. Bomb fuzes and boosters must not be allowed to become adrift and abused. This may render them unreliable and unsafe, creating an explosion hazard in the area. With the nonstandard stowage methods to be found at advance bases, it may be expected that ammunition components may more easily become adrift than at permanent magazines. A closer watch will have to be made for such a condition.

Stowage of bomb stores outdoors necessitates that they be piled or lined up horizontally on level dunnage to obviate their falling or rolling and striking others nearby. They should never be stood on end or leaned against any form of support. Storing bombs on ground areas requires that they be supported by relatively thick dunnage to form an adequate air space between them and the ground. Logs may be split and used for dunnage. Where the ground is soft, it may be wise to use the whole log (not split) to minimize settling of the dunnage. Bombs of different types held in reserve should be stowed in separate revetments or dumps if at all possible. Completely assembled bombs should never be stowed with the reserve bombs at any time. However, it is a good idea to stow crated tail vanes for any stock of bombs with the bomb bodies. This will facilitate supply of both items.

Especially at advance bases, shipping bands (lug guards) should not be removed from the bomb bodies until just prior to assembly and/or use. Bombs returned unused from missions, or those assembled and not used, may be left assembled, BUT THEY MUST BE UNFUZED. These should then be stowed one layer deep on dunnage, with tails alternately pointing in opposite directions near the airstrip. Tail vanes, due to their sheet metal construction, are more susceptible to damage than bombs themselves. Therefore, it is best to leave them in their crates until the are needed.

Rocket-Type Munitions

Some aircraft rockets are shipped disassembled. Heads, motors, and fuzes are shipped separately. One fundamental rule in rocket handling and stowing is that they should never be assembled except just prior to issue for use. Rocket components are placed in segregated stowage and, as far as practicable, separate from other types of ammunition. At advance bases where space may be limited, it is permissible to stow rocket motors with smokeless powder charges, the heads with projectiles, and the fuzes with bomb-type fuzes. In this even, all other safety precautions must be observed and care is exercised in issuing these components so as not to cause confusion. Rocket fuzes are issued in metal containers and should be handled the same as bomb fuzes as to precautions necessary.

Rocket motors require special handling not afforded any other type of ammunition. They might even be called delicate and sensitive in the extreme. Ignition of their ballistite charge, or grain, is accomplished by an electrical impulse transmitted through wires to their igniters through the surface of the motor shrouds. Corrosion cannot be allowed to build up on these surfaces. In cleaning off any corrosion, sandpaper (fine) may be used, but NOT wire brushes and emery cloth. These last two devices might possibly cause production of sufficient static electricity to set off the black powder igniter squib. Rigid precautions have to be taken to insure that rocket motors are not stowed or allowed to be passed near such energy producing components of electronic gear as antenna lead-in wires, high voltage electric circuits, and radar magnetrons. These components may cause rocket motors to ignite through radiated electrical energy.

Contact surfaces and threaded sections of the rocket components should be preserved with a light coating of mineral grease to prevent corrosion, especially while stowed at advance bases. Components that have become badly corroded, bent, lost motor caps, been dropped forcibly enough to possibly break the powder grain, or subjected to other damages, will be set aside and not used. The motors are highly sensitive to moisture. As a result, they should at all times be stowed under cover upon suitable dunnage.

Stowing a completely assembled rocket, unless designated to be so stowed is the same as stowing a loaded gun. As a consequence, they are never assembled into complete rounds until immediately before use unless the tactical situation dictates otherwise. When assembled, complete rounds of rockets should be stowed only in ready service lockers or in revetments, behind shields and barricades, and other equally safe locations. Unassembled rocket motors are chiefly fire hazards due to the relatively unconfined condition of the propellant grain. They would be classified as smokeless powder rather than explosives.

Rockets may not be fired if the propellant temperature is below or above the temperature limits stenciled on the motor. In temperature extremes, the motors will have to be stowed in proper locations for 6 or more hours for the propellant temperatures to stabilize within these two figures. A temperature insensitive rocket propellant is now replacing present inventories and should simplify the handling and stowage problems connected with rockets.

SAFETY PRECAUTIONS

General

Safety precautions concerning ammunition stowage and handling, due to the inherent dangers associated with ammunition in general, are far reaching in scope. In spite of this fact, detailed precautions have not been overlooked. There are precautions affecting each component and complete round of ammunition, covering in minute detail all of the precautions necessary to be observed.

One of the first general precautions to be remembered is that when there is the slightest doubt as to the exact meaning of a particular safety precaution, AN INTERPRETATION SHALL BE REQUESTED FROM THE BUREAU OF ORDNANCE. The method of communicating with the Bureau will be determined by the seriousness of the situation. There may arise situations for which there are no safety precautions written. The commanding officer may recognize that unsafe conditions exist in this situation. However, he will find nothing in any of the safety precautions or regulations which may be construed as authority to continue operation under the existing situation. He must either cease operations entirely, or hold further operations in abeyance until advice can be received from the Bureau of Ordnance.

Safety devices provided for handling and stowage of ammunition shall be used consistently without fail. These devices shall be kept in good order and operative at all times. They are there for the protection of all hands. Further, all operating instructions for such equipment shall be rigorously observed.

Changes, modifications in, or additions to ordnance material shall not be made without explicit authority from the bureau or bureaus concerned. No ammunition or explosive assembly shall be used in any gun or device for which it is not designated.

Familiarity with any line of work, no matter how dangerous, is apt to lead to carelessness. Personnel supervising or performing work in connection with the inspection, care, preparation, use, or handling of ammunition and explosives shall exercise the utmost care that all regulations and instructions are rigidly observed. They shall also carefully supervise those under them and frequently warn them of the necessity of using the ultimate precaution in the performance of their work. NO RELAXATION OF VIGILANCE SHALL EVER BE PERMITTED.

All ammunition, explosives, and powder shall be protected from abnormally high temperatures. If so exposed, they shall be handled in strict accordance with the latest *Bureau of Ordnance Instructions*. The Bureau prescribes the maximum allowable storage temperatures for all types of ammunition.

Smokeless powder which has been wet from any cause whatever must be considered dangerous and shall be handled as prescribed by the Bureau of Ordnance. Also, smokeless powder which shows unmistakable signs of advanced decomposition shall be disposed of according to current instructions from the Bureau.

In order to minimize the dangers of fire, explosion, and damage to ammunition and its containers from accidental causes, ammunition shall be handled as little as possible. Denting of thin-cased high explosives has caused detonation of the explosive in some instances.

Any fuzed projectile dropped from a height of 5 feet or over shall be, if practicable, returned to the nearest naval ammunition depot. If not, it should be dumped overboard as prescribed in current instructions.

Magazines shall be kept scrupulously clean and dry at all times. Nothing shall be stowed in magazines except explosives, containers, and authorized magazine equipment. Particular attention shall be paid to the prompt removal and/or prohibition of introduction of oily rags, waste, or other foreign materials susceptible to spontaneous combustion in magazines.

Naked lights, matches, or ANY other spark or flame-producing device shall never be taken into magazines or other spaces used primarily as magazines as long as the spaces therein contain explosives. Before performing any work which might cause either an abnormally high temperature or intense local heating in a magazine, all ammunition shall be removed to safe storage until normal conditions have been restored.

Black powder is one of the most dangerous of explosives and shall always be kept by itself. Only such quantities as are immediately needed shall even be broken out of the magazine. A container of black powder shall never be opened in any magazine, nor in the vicinity of a container in which there is any explosive.

Ammunition shall not be altered, nor shall fuzes or any other parts be removed or disassembled without explicit instructions from the Bureau of Ordnance.

Ammunition will be handled under the direct supervision of qualified personnel who understand thoroughly the hazards and risks involved. Personnel handling ammunition will be impressed with the fact that their safety, as well as that of others, depends upon the intelligence and care exercised by themselves and their shipmates.

The handling of ammunition should always be conducted so that a limited number of personnel are involved—the smallest number compatible with the work to be done.

Charges of static electricity can be accumulated on a person and on explosive materials such as smokeless powder. The discharge of static electricity is a serious hazard in the presence of certain exposed explosives, dust and air mixtures, and inflammable vapor and air mixtures. Processing equipment for such materials subject to static discharge should always be grounded. Workbenches should be covered with electrically grounded conductive materials as should be the decks wherein possible. Safety shoes which will not cause sparks should be issued to all personnel performing certain types of ammunition overhaul and maintenance work. Cushioned metal chairs are a source of static electricity generation when in use under certain atmospheric conditions; they should not be used around ammunition and explosives.

Drivers, both Navy and civilian, engaged in the operation of Navy vehicles carrying explosives shall understand that, during the time they are operating such vehicles, they bear responsibility and personal liability as agents of the Navy for any damages resulting from their negligence. This applies both to their driving and wrongful operation of their vehicles.

The explosive driver shall be required to carry with him, while driving, his doctor's certificate (or photostat of same), and shall be responsible for keeping his certificate current by submitting to re-examination at specified intervals appropriate to his age group. It shall be the duty of the explosive driver of a truck loaded with dangerous cargo to be certain that proper dangerous cargo placards have been affixed to his vehicle in the specified locations prior to his departure for an off-station trip.

Carbon tetrachloride shall NOT be used for cleaning purposes except by express authorization by the commanding officer or his executive officer. The fumes are highly toxic even in moderate concentrations. Carbon tetrachloride is frequently the cause of skin troubles if used in excess. When heated above a specific temperature, phosgene gas is formed as a byproduct. This is the same poisonous gas as used in World War I.

Specific

It would not be at all practicable to mention in this chapter all of the safety precautions connected with the stowage and handling of ammunition. It would require too much space. However, any and all safety precautions are important because most of them were written as the result of some damaging or fatal incident. None should be overlooked or slighted. With this in mind, the following publications, or sections thereof pertinent to the work being conducted, should be studied prior to commencement of the actual work if not already well in mind.

Bureau of Ordnance Manual, 1955

United States Navy Safety Precautions, 1953, OpNav 34P1

Safety Precaution, NavOrdInst 5100.1

Ordnance Safety Precautions, Their Origin and Necessity, OP 1014

Torpedo Safety Precautions, OP 2099

Clearing of Live Ammunition From Guns, OP 1591

Index of Ordnance Publications, OP 0 (See index for pertinent precautions.)

HANDLING EQUIPMENT.—Safety precautions concerning handling equipment are as necessary and important as those for ammunition itself. If the ammunition cannot be handled in complete safety with the available equipment, it should not be handled at all. The following are some of the more pertinent precautions:

1. Prior to using a bomb truck, fork lift, bomb skid, bomb elevator, and any other piece of handling equipment, its operation should be checked thoroughly and its condition (general) should be noted.

2. Before operating a specific piece of gear or equipment, the operator shall have been completely familiarized with its use and in its use.

3. Preventive maintenance will be regularly performed on each piece of handling equipment between overhauls.

4. Specific instructions will be studied prior to performing maintenance on any piece of handling equipment.

BOMB-TYPE AMMUNITION.—The following are some of the more pertinent safety precautions concerning bombs and mines:

1. Check bombs and mines at inspection periods regularly for exudate. Clean off as prescribed and/or remove the affected ammunition from the magazine.

2. Most of this type ammunition is thin walled. Therefore, it, as a class, will have to be handled with even more care than ammunition with thick walls.

3. Smoke bombs of all types shall not be stowed with high explosives.

4. No miniature practice bomb will be stowed in a magazine with the cartridge installed therein.

5. Loaded practice bombs cannot be dropped without danger of being set off. These bombs are about the most dangerous ammunition in the Navy—not in explosive strength, but in injury to personnel through accidental discharge, causing burns from flame and possible fatal injury due to shrapnel from rupture of the case.

AIRCRAFT ROCKETS.—Rockets require special handling and stowing measures as they are easily damaged beyond serviceability. The heads are classed as explosive hazards and the motors as fire hazards. The following precautions should be observed:

1. Unless received assembled, never assemble complete rounds until the rockets are ready for use.

2. Keep rocket motor temperatures between 10° F. and 100° F. The complete round whose motor is at temperatures outside of the limits of those shown on the motor tube cannot be fired. Allow a stabilizing period of 6 hours for the round to resume safe firing temperature before loading for use.

3. Corrosion on the motors may be removed with sandpaper only. NEVER use wire brushes or emery cloth.

4. Keep rocket motors away from antenna lead-ins, radar components, and other energy emitting electronic equipment. Motors can be fired by these devices when they are in operation if placed close enough to them.

5. Never fire a rocket in which the grain (propellant) has been broken or otherwise damaged. It may misfire or explode instead of burning progressively.

PYROTECHNICS.—These devices have been likened to "fireworks" for good reasons. They are easily set off and will quickly ignite other inflammables and devices nearby. Precautions regarding these devices are as follows:

1. Care has to be taken to dissipate static electrical charges before they are able to reach pyrotechnics. Sparkproof shoes, tools, and other safety items should be employed in working with pyrotechnics generally. Nothing but fine sandpaper will be used for cleaning corrosion from metal shrouds and bodies of pyrotechnic ammunition.

2. Stow pyrotechnics in a dry environment at all times. Moisture quickly deteriorates these munitions, rendering them completely unserviceable.

3. Stow pyrotechnics well away from all sources of radio energy emissions such as those from radar, antenna lead-in, etc. Pyrotechnics have been fired from such sources.

4. Always have readily available sufficient and proper fire fighting equipment when handling pyrotechnics.

BOOSTERS.—To the inexperienced eye, boosters are inoffensive looking items, generally speaking. Nothing could be further from the truth; they are deadly. It is important to learn to recognize all types of these munitions. Some of the precautions necessary when handling boosters follow:

1. Never jar, drop, or otherwise subject boosters to shock. They are sensitive to both shock and friction.

2. Secure covers of the wooden boxes containing boosters with screws—never by nailing.

FUZES.—Fuzes contain various types of delicate mechanisms. They are easily damaged if improperly handled. Pertinent precautions concerning fuzes follow:

1. Any fuze from which the safety pin has been removed must be considered armed. No exceptions are considered.

2. The safety pin will never be removed until AFTER the arming wire has been inserted in the fuze vane assembly of the bomb.

3. A fuze dropped from a height greater than 5 feet must not be installed in a bomb. It will be set apart for disposal in accordance with latest directives and instruction.

4. Only technically qualified personnel will install anti-removal fuzes.

JATO (JET ASSISTED TAKEOFF AMMUNITION).—JATO devices are normally classed as fire hazards except for some used to boost the initial thrust of guided missiles. Safety precautions regarding this device follow:

1. Some older JATO bottles shall always be stowed in an upright position. Stowing in any other position causes the contained propellant to "flow" into a position in which the surface area at the top of the propellant is

changed to a greater value. Upon firing, more than a normal surface area will be exposed to burning, thus creating damaging pressures within the container. The container may even rupture or explode. The bottles requiring such stowage will be so marked.

2. Treat JATO devices as missile hazards at all times.

3. Insure that the shorting clip is in place at all times. Remove it only when ready to install the firing circuit pigtail.

FIXED AMMUNITION.—This ammunition is generally thought of as more or less harmless in being handled and stowed in comparison to other types of ammunition. However, there are a number of safety precautions to be observed if fixed ammunition is to be handled and stowed safely. Some of these precautions follow:

1. Never break down any type of fixed ammunition.

2. Fixed ammunition with explosive projectiles are especially dangerous. Do not drop, tumble, or otherwise subject this ammunition to external forces.

3. When firing fixed ammunition and a misfire occurs, do not attempt to clear the bore unless thoroughly familiar with the contents of OP 1591, *Clearing Live Ammunition From Guns.*

INERT MUNITIONS.—Inert ammunition is cutaway, dummy, and plaster filled munitions, and such items as tail vanes, etc. Although not dangerous in the general sense of the word, there are still reasons for observing certain safety precautions in its handling. The following precautions obtain:

1. The weight and mass of inert ammunition require that it be handled properly and safely. It can easily crush a man if it should fall or tip over on him. Such components as bomb tail vanes can inflict serious cuts.

2. Tail vanes will have to be handled carefully as they are usually made from relatively thin sheet metal and bend easily. Bent fins on a bomb cause erratic flight of the bomb.

SMOKE AMMUNITION.—As a class, smoke ammunition is dangerous. It has to be handled with extreme care lest it become either a fire or corrosion hazard. The following precautions obtain:

1. Wear protective clothing when handling FS smoke materials.

2. Do not allow FS liquid to come in contact with water and oils. A violent reaction follows when this occurs.

3. In the event that FS materials come in contact with the skin, wash copiously with water in which bicarbonate of soda has been dissolved.

4. Handle smoke bombs like any other pyrotechnic ammunition.

TORPEDOES.—These munitions are extremely dangerous with or without their warheads. Some of the precautions follow:

1. Take great caution not to trip the firing mechanism by pulling the starting lanyard. A "cold run" caused by energizing the starting mechanism will result in components flying apart if the torpedo is not in the water.

2. The contained air flask is charged under high pressure. If the torpedo is allowed to drop, it is possible for this flask to rupture, causing injury to personnel and damages to nearby equipment.

3. Insure that the propeller lock is always installed correctly and stays there until the torpedo is loaded on the aircraft.

AMMUNITION STOCK RECORDING SYSTEM

Purpose and Scope of System

The Ammunition Stock Recording System is designed to provide, to the greatest extent practicable, a standard and definite system for recording all transactions involving ammunition and ammunition components in the records of the local station as well as in the consolidated records prepared by the Naval Gun Factory for the Bureau of Ordnance. Further provisions are incorporated for recording these ammunition transactions in the appropriate class cognizance ledgers, the work-in-progress accounts, and the stores accounts.

The Ammunition Stock Recording System (ASRS) also provides accurate, up-to-date information as to the quantity and quality of all ammunition and components on hand, obligated or due in, in order that the best possible stock position on ammunition items can be obtained. This information should:

1. Afford expeditious issues.
2. Maintain effective control over restricted, unserviceable, or obsolete ammunition.
3. Maintain effective control over basic stock.
4. Maintain effective distribution of stock between ammunition activities.
5. Maintain effective planning of productive operations.
6. Maintain adequate allowances to fulfill ship requirements.

And finally, the ASRS provides the Bureau of Ordnance, via the Naval Gun Factory, proper and sufficient information of the most timely and accurate quality so that the Bureau may effectively plan stock purchase budgets, procurement, production, maintenance, and distribution of ammunition and its components.

The ASRS is applicable to the ammunition shown in table 10–1. This indicates the coverage and scope of the system.

Table 10–1.—Ammunition code classification.

Material class for accounting purposes	ASRS classes	Material description	Section number in ammunition Code Catalog OP 1219
J 13 for all ASRS coded ammunition items under the inventory control of the Bureau of Ordnance.	A	Bombs and accessories	OP 1219A
	B	Pyrotechnics	OP 1219B
	C	Miscellaneous chemical ammunition and chemicals.	OP 1219C
	D	Depth charges and accessories.	OP 1219D

Table 10–1.—Ammunition code classification.—Continued

Material class for accounting purposes	ASRS classes	Material description	Section number in ammunition Code Catalog OP 1219
	E	Demolition materials ---	OP 1219E
	G	Mines and mine materials.	OP 1219G
	1 & R	Gun ammunition, 20- and 40-mm.	OP 1219R
	4	Unserviceable ammunition (gun), overage.	OP 1219R
	8	Unserviceable gun ammunition (limited identification).	OP 1219R
	9	Unserviceable gun ammunition, specific defect.	
	J	Projector charge and rocket ammunition assemblies.	OP 1219J
	K	Dummy ammunition assemblies and miscellaneous charges and cartridges.	OP 1219K
	L	Marine Corps ammunition.	OP 1219L
	M	Projector charge and rocket ammunition components.	OP 1219M
	N	Fleet return projector charge and rocket ammunition.	OP 1219N
	O	Gun ammunition components and miscellaneous items.	OP 1219O
	5	Small arms, machine gun, and aircraft gun ammunition.	OP 1219P
	6	Marine Corps and landing party ammunition.	OP 1219Q

All ammunition under the ASRS handled by stations is considered to be either STOCK OR NON-STOCK. "Stock" by definition is all ammunition and components thereof which is "owned" and accounted for by a station. Stock ammunition is divided into three categories: Coded, Uncoded, and Not Coded. CODED ammunition is carried as stock for issue by stations and has been coded. UNCODEABLE ammunition is so designated because all of the identifying characteristics are not known. Should the characteristics become known, it may then be transferred to the code thereto assigned. NOT CODED ammunition is carried by stations, but since it is of minor importance or of experimental nature, the Bureau of Ordnance does not desire to have it coded. Although it may be completely identified as to characteristics, it is still carried as Not Coded.

Non-Stock ammunition is that material in temporary custody of a station, but which is assigned to an outside activity or controlled thereby. The station does not account for nor take title to this type ammunition.

The following types of shore activities use the ASRS to report all Navy-furnished ammunition of the classes previously shown in this chapter:

1. Naval ammunition depots.
2. Naval ammunition and net depots.
3. Naval magazines.
4. Naval magazines and net depots.
5. Naval operating bases.
6. Naval mine depots.
7. Naval air stations.
8. Naval air facilities.
9. Marine Corps air stations.
10. Naval section bases.
11. Naval fuel depots.
12. Any other Navy activities acting as sources of supply or issuing activities for ammunition.

When the Ammunition Stock Recording System was created, certain principles of a basic nature were borne in mind and incorporated into the system. These principles were:

1. Wherein possible, documents which cause materials to be moved into and out of store will also be used for stock recording, stock reporting, and financial accounting purposes.

2. The number of transaction documents used to effect the movement of materials will be kept to a minimum. The transcription of the same information from document to document in effecting a transaction will be avoided wherever possible.

3. Class cognizance ledgers shall be maintained in a current condition.

4. Balances on stock records will reflect only the material in store.

5. The In-Progress accounts for job orders (as maintained by the Fiscal Division) will fully accumulate on a current basis all data necessary to provide the status of a given manufacturing job.

6. Provide the Bureau of Ordnance, via the Naval Gun Factory, with timely and accurate information relative to stock status at field activities.

Description and Procedures

The two basic documents used for recordkeeping in the Ammunition Stock Recording System are the Ammunition Invoice (A/I) and the Receipt Expenditure Transfer Report (RETR). The Ammunition Invoice is used to record and process ammunition transactions such as receipts from other naval activities, receipts from nonnaval activities, and receipts from nonnaval sources such as the Army and private contractors, off-station shipments of ammunition transferred to other naval activities or issued to ships. The Receipt Expenditure Transfer Report is used to record internal or intrastation types of movements such as the issue of ammunition for use in test and surveillance purposes; and the issue of components to station production for assembly, breakdown and reassembly operations.

The RETR is also used for recording the return of finished goods from the station production building to the magazines as a result of assembly, breakdown, or breakdown and reassembly operations. It is likewise used in certain types of material adjustments, code changes, or status changes. And finally, this record is used to record local transfers within the station such as those necessary when ammunition is moved from one building or magazine to another magazine during the course of a restorage program.

The Ammunition Stock Recording System, as currently implemented, offers many benefits and improvements over earlier versions of this system. Some of the benefits to be derived and principles to keep in mind when employing the current implementation are:

1. There is a substantial reduction in the number of documents necessary to successfully employ the current system.

2. Ordinarily, the documents employed will record an ammunition transaction from the beginning of the transaction to its completion. A few exceptions to this principle have been provided for in the cases of ammunition receipts from nonnaval sources and in survey procedures.

3. The documents employed to record transactions in the Ammunition Stock Recording System and in the local ordnance departments will be passed on through the Supply and Fiscal departments for recording money values on ledgers.

4. For accounting purposes, the various types of work performed by station production facilities have been grouped into three categories: Station Production; Station Breakdown, Breakdown and Reassembly; and Station Processing. Station Production consists of new assembly (ammunition) for which the cost of labor, materials, and overhead is accumulated and assigned to a specific expenditure account. Station Breakdown, Breakdown and Reassembly consists of operations for which the cost of labor, materials, and overhead is accumulated and assigned to another specific expenditure account.

Station Processing covers other types of work performed in the production plants which generally changes only the condition rather than the physical identity of the material. Overhaul, repair, reconditioning and exterior maintenance are examples of Station Processing. Ammunition items, components, and/or details scheduled for Station Processing are issued and returned by quantity only under the Receipt Expenditure Transfer Report form.

5. The accounting records for job orders covering manufacturing jobs, as maintained by the fiscal division, will fully accumulate all the data necessary to provide a comprehensive story concerning a given manufacturing job at any point in the progress of a particular job.

6. The System will maintain an ammunition lot history as an inherent part of the job order folder.

7. Because of the current sequence of recording transactions in the Ammunition Stock Recording System, the availability reports, furnished to the Bureau of Ordnance, reflect accurate data on availability or nonavailability of stocks of ammunition at a particular station.

8. Under the current implementation, coordination between the quantities on the ammunition stock records and their respective values on the class cognizance ledgers have improved drastically. This results in a great reduction in the previously large annual adjustments necessary.

Coding and Code Structure

When new items of ammunition are received, the receiving station first attempts to code the items by reference to the code catalog. Failing this, a "Request for Ammunition Catalog Assignment" form is completed in duplicate and sent to the Naval Gun Factory for codification. This request must be submitted even though the only difference between the item to be codified and one like it already listed in the catalog is a change in modification (Mod). Every attempt should be made to obtain the basic information with which to code the item. Indicate such information as contract number, all container markings, etc., in the request for coding to the Gun Factory. During the time that the request for coding is at the Gun Factory, all stock cards and documents reporting transactions in the items concerned MUST show reference to the request for code which is pending. As soon as the Gun Factory returns the request, all records must then be brought current by substituting the code, or other information supplied by the Gun Factory, in place of the reference to the code request.

The Bureau of Ordnance is the sole authority for the preparation and assignment of basic ammunition codes; those which normally reflect the condition SERVICEABLE. Those in which the basic code reflects the condition of UNSERVICEABLE will be altered by the field stations. Each station, by altering the basic code, reports each item of material under the appropriate condition code. Condition codes are those which reflect the status of the materials. These conditions are: Serviceable, preserved, incomplete, and repairable.

The code structure for the various items of ammunition are outlined below.

CODE CLASS A.—This code consists of a 7-digit number. The first and second digits are arbitrarily assigned to indicate the general type of items. The third, fourth, and fifth digits are arbitrarily assigned, and the sixth digit indicates each item's condition (serviceable, unserviceable, etc.). The seventh digit, which is an A, indicates the class, or bombs and accessories.

CODE CLASS B.—This code covers all pyrotechnics and consists of 6 digits. The first digit is arbitrarily assigned and indicates the general type of items. The second and third digits are generally used to indicate a major division within a type. The fourth digit, generally an arbitrary assignment, distinguishes particular items within the major division. The fifth digit shows the condition, and the sixth digit indicates the class (pyrotechnics).

Code Class C.—This is the miscellaneous chemical ammunition and chemical code. It consists of 6 digits. The first 4 digits are arbitrarily assigned to indicate the general type of items. The fifth digit indicates the condition, and the sixth digit indicates the class.

Code Class D.—Depth charges and accessories are contained in this code. It consists of 8 digits. The first and second digits are arbitrarily assigned to indicate the general type of items. The third digit indicates the oading of the charge. The fourth and fifth digits indicate the "Mark" of the ammunition. The sixth digit ndicates the "Mod" of the item. The seventh digit indicates the item's actual condition, and the eighth digit shows the class.

Code Class E.—Code E contains demolition materials. It has an 8-digit number. The first and second digits are arbitrarily assigned to show the general type of items. The third and fourth digits show the "Mark" when applicable. The fifth and sixth digits indicate the "Mod" and are arbitrarily assigned. The seventh digit shows the condition of each item. The eighth digit shows the class.

Code Class G.—Mines and mine materials make up this code group. The code consists of 9 digits. The first digit is arbitrarily assigned to indicate the general type of items. The second and third digits indicate the "Mark" for mine assemblies. The fourth and fifth digits indicate the "Mod" for mine assemblies, but show the "Mark" for other items when applicable. The sixth digit indicates the type of loading for mine assemblies, and for other items it shows the "Mod" when applicable. The seventh digit indicates the variations in the assembly of components and is assigned arbitrarily. And the eighth digit shows the item's actual condition. The ninth digit indicates the class.

Code Class J.—Projector charge and rocket ammunition assemblies are contained in this code class, which bears an 8-digit number which is preceded by the caliber when applicable. The first and second digits are arbitrarily assigned to indicate the general type of item. The third, fourth, fifth, and sixth digits are arbitrarily assigned to indicate the various subdivisions within the general type. The seventh digit indicates the item's condition, and the eighth digit indicates the class.

CODE CLASS K.—This code contains dummy ammunition assemblies and miscellaneous charges and cartridges. It consists of an 8-digit code. For certain types of items the code is preceded by a caliber designation. For DUMMY AMMUNITION ASSEMBLIES, the first digit indicates the major groupings. The second, third, fourth, and fifth digits generally indicate the "Mark" and "Mod" of the round. However, for dummy powder charges, the second and third digits are used to indicate the material from which the round was made, and the fourth and fifth digits are assigned arbitrarily. Where applicable, the sixth digit indicates the type of dummy nose fuze or plug. For MISCELLANEOUS CHARGES AND CARTRIDGES, the first two digits indicate the general type of items. The third digit indicates a subdivision within a type. The fourth, fifth, and sixth digits are arbitrarily assigned to distinguish particular items within a subdivision. For ALL Class K items the seventh digit indicates each item's condition, and the eighth digit indicates the item class.

CODE CLASS L.—The codes for this ammunition material have been released informally to the major participants of the ASRS who store and ship this type under current instructions of the Bureau of Ordnance. The code structure for Code Class L is similar to that of Code Class 6. This code is constructed, when possible, utilizing Army codes. Upon distribution of the catalog for this code (OP 1219L), detailed information will be contained concerning code structure, code assignment authority, and reporting procedures for this ammunition.

CODE CLASS M.—Class M concerns projector charges and rocket ammunition components. The code consists of eight digits, preceded in some cases by the actual caliber. The first and second digits show the major classification for the item. The third digit indicates the item's actual condition. The fourth and fifth digits show the actual "Mark" of the item if applicable; otherwise they are arbitrarily assigned. The sixth and seventh digits are the actual "Mod" of the item as applicable; otherwise these digits are arbitrarily assigned. The eighth digit, which is an M, indicates the class of the material.

CODE CLASS N.—Fleet returned projector charges and ocket ammunition are concerned in this code. The Code Class N applies to all fleet returned ammunition of he above types until such a time as the ammunition can be inspected and its identity determined. After examination and rework, the identified items are transferred o Class J or Class M as applicable. The code consists of seven digits, proceded in some cases by the actual caliber. The first and second digits are arbitrarily assigned to indicate the general type of the items. The hird and fourth digits are also arbitrarily assigned to ndicate the loading of the heads. The fifth digit is also arbitrarily assigned to indicate the packing. In the case of FUZES, the third, fourth, and fifth digits are the item's actual "Mark." The sixth digit (a 0) indicates all "Mods." The seventh digit, which is an N, indicates the material class.

CODE CLASS O.—This class contains gun ammunition omponents and miscellaneous items. It has eight digts in the code, preceded in some cases by the actual aliber. The first and second digits are arbitrarily asigned to indicate the general type of items. The third digit indicates the item's actual condition. The fourth and fifth digits show the actual "Mark," but when not applicable, these digits are arbitrarily assigned to show other variations. The sixth and seventh digits are the actual "Mod" of the item, but if not applicable, they are arbitrarily assigned to indicate other variations. An O is the eighth digit and indicates the material class.

Code Class 5.—This class contains all the small arms, machine gun, and aircraft gun ammunition. The code itself contains 6 digits. The sixth digit is a 5 to indicate the proper ASRS class. With certain exceptions, the first five digits of the code are derived from Army codes. Each station shall report each item of this material under the proper code for its actual condition by altering the fifth digit of the code to an 8 or 9 as appropriate.

Code Class 6.—The ammunition contained in this class is that used by the Marine Corps and for landing force parties. The code for the SERVICEABLE part of class 6 material consists of six digits. The first five digits of the serviceable code are derived from Army codes. The sixth digit is a 6, and indicates the class material. Codes for Code Class 6, OTHER THAN SERVICEABLE and which are identified by caliber and type, contain SEVEN digits. An additional digit, either an 8 or 9, is inserted in the serviceable code preceding the final class digit 6. Each station shall report each item of this material under the proper code for its actual condition by inserting an additional digit to the basic code as appropriate.

Detailed information and all the instructions necessary for coding of all types of Navy ammunition will be found in the *Ammunition Code Catalog,* OP 1219, latest revision. This publication, with all its several parts, should be contained in the files of each activity held accountable and otherwise responsible for ammunition. Much valuable information concerning coding, as well as detailed information on the ASRS, will be found in the current issue of the *Ammunition Stock Recording Procedures Manual,* OP 1675 (Rev.).

QUIZ

1. The color code of a magazine containing bombs is
   - a. orange
   - b. red and yellow diagonal
   - c. red
   - d. yellow

2. The regulations governing the transportation of ammunition are set forth in/by the
   - a. *Bureau of Ordnance Manual*
   - b. Bureau of Yards and Docks
   - c. Interstate Commerce Commission
   - d. OpNav Inst. 5500.1

3. Magazine temperature reports are made by each command accountable for ammunition
   - a. daily
   - b. not later than thirty days
   - c. every seventy-two hours
   - d. first and fifteenth day of each month

4. Operating and service squadrons are required to submit to the station at which they are based an ON HAND inventory of aviation equipment
   - a. monthly
   - b. as a situation report
   - c. bimonthly
   - d. annually

5. The aviation ordnance equipment reported on the ON HAND report is consolidated and sent to the
   - a. air group
   - b. FASRon
   - c. Navy Air Base Command
   - d. NAS Magazine

6. The Armory and Magazines Officer is under the
   - a. Ordnance Officer
   - b. Gunnery Officer
   - c. Ship's Gunner
   - d. Aviation Ordnance Officer

7. All leading petty officers of the Air Department work directly under the ________ in the receipt and delivery of ammunition
   a. Aviation Ordnance Officer
   b. Aviation Ordnance Gunner
   c. Gunnery Officer
   d. Ordnance Officer

8. Damaged ammunition is generally more ________ than that which is serviceable.
   a. hygroscopic
   b. dangerous
   c. powerful
   d. brisant

9. How many standard type magazines are there?
   a. 16
   b. 8
   c. 24
   d. 12

10. In the diagram, what does the number "7" indicate?
   a. Magazine number
   b. Group number
   c. Code number
   d. High explosive magazine

Yellow
7DT 28
background

11. What does the letter "T" indicate in the above diagram?
   a. Earth covered but not barricaded
   b. Dome corbetta
   c. Barricaded
   d. Substandard explosive magazine

12. The color background of a small arms and pyrotechnic magazine is
   a. blue
   b. white and yellow striped
   c. brown
   d. white

13. The color background of a magazine containing black powder is
   a. green
   b. blue
   c. red and yellow striped
   d. yellow

14. The letter "Y" on a nonstandard magazine stands for
   a. powder magazine
   b. explosive magazine
   c. projectile magazine
   d. high explosive magazine

15. Quantity and distance tables are found in what publication?
    a. OP 4
    b. *Bureau of Ordnance Manual*
    c. *Interstate Commerce Commission Regulations*
    d. OP 5

16. A rocket motor in storage is a
    a. missile hazard
    b. explosive hazard
    c. fire hazard
    d. nonexplosive hazard

17. The explosive charge in the igniter of a rocket motor is
    a. smokeless powder
    b. ballistite
    c. black powder
    d. cordite

18. Normal stowage temperature of rocket propellant is
    a. –10° to 100° F.
    b. –60° to 150° F.
    c. 0° to 130° C.
    d. –10° to 120° F.

19. If exposed to above or below normal temperature, the rocket motor will have to be stowed in proper locations for ________ or more hours for the propellant temperature to stabilize.
    a. 5
    b. 4
    c. 6
    d. 8

20. When there is the slightest doubt as to the exact meaning of a particular safety precaution, an interpretation shall be requested from the
    a. Naval Gun Factory
    b. Interstate Commerce Commission
    c. Bureau of Ordnance
    d. Commanding Officer

21. Under ASRS, class B contains information on what type of ammunition?
    a. Dummy ammunition
    b. Bomb type ammunition
    c. Small arms ammunition
    d. Pyrotechnics

22. Stock ammunition is divided into three classes: coded,
   a. not coded, and uncoded
   b. uncodeable, and not coded
   c. codeable, and not coded
   d. not coded, and noncodeable

23. Which of the following would not come under the ASRS?
   a. NAD
   b. NAS
   c. FASRon
   d. Navy fuel depots

24. A movement of ammunition between NAS and FASRon would be reported on what report?
   a. A/I
   b. RETR
   c. Ammunition Report
   d. Transfer Report

25. What publication would you consult to determine the correct code for ammunition component?
   a. OML's
   b. OCL's
   c. OP's
   d. OD's

CHAPTER 11

ADMINISTRATION

A thorough working knowledge of ordnance administration should enable a leading aviation ordnance petty officer to perform his duties without hesitancy. When such a man is assigned a task, he will know where to get needed information immediately, he will know how to replace parts required by his activity, and he will be able to secure the necessary equipment without delay. On a day-to-day basis, the knowledge he possesses will be reflected in the smoothness and ease with which he works and in the efficiency of his activity with regard to ordnance matters. Any first or second class aviation ordnance petty officer competing for advancement in rating should understand that a sound knowledge of aviation ordnance administration is of utmost importance PRIOR to his entering the competition.

AVIATION ORDNANCE AND ARMAMENT SUPPLY

The Bureau of Ordnance furnishes aviation explosive ordnance and guns. The Bureau of Aeronautics furnishes armament equipment, such as bomb racks, bombng systems, fire control systems, turrets (less guns), rocket launchers, targets, and practice bomb containers. The majority of the supply work throughout the Navy s accomplished by supply personnel. However, it must be remembered that the supply functions cannot anticipate nor would they even hazard a guess as to the actual needs of an operating squadron much less the needs of an ndividual department within an activity. There are, naturally, certain specified allowances compiled for specific types of operating activities. But these supply functions cannot predict with any degree of accuracy the quantities of each type item that will be expended and otherwise used. It then becomes necessary for all leading ordnance petty officers to become familiar with the Navy supply system, at least to the degree in which a working knowledge of the system is obtained. In order to operate properly, no squadron may long be without sustained logistic support in all matters of supply. Ordnance material constitutes one of the important elements of the supply problem. Regardless of the high level of training attained by squadron personnel, their hands are tied if they do not have sufficient and proper armament and stores with which to utilize their aircraft to maximum capabilities.

Aviation ordnance leading petty officers have a responsibility to their respective activities in assuring that there is on hand, ready for immediate use, the proper types and quantities of armament stores and replacement items. To make such a condition plausible, it is necessary under certain conditions to have and maintain an ordnance storeroom. It is for this reason that the leading petty officer should necessarily know how to stock, handle, store, order, and maintain an ordnance storeroom. His working knowledge should embrace allowance lists and sheets, accountability, forms ordering, preparation of ammunition performance reports, and other areas of work connected with operating and maintaining an ordnance storeroom.

The Navy Supply System

The chain of supply along which aviation ordnance materials move consists of RESERVE STOCK POINTS, DISTRIBUTION POINTS, PRIMARY STOCK POINTS, AND SECONDARY STOCK POINTS. Materials flow through these facilities until they reach the operating activities at which they are put into use. The Bureau of Ordnance sets up these supply facilities in the localities best suited as distributive points and designates the specific purposes that they are to serve.

Contracts for manufacture of aviation explosive ordnance are issued to the various manufacturers by the Bureau of Ordnance. After the desired materials have been produced and meet the specifications required by the Bureau, they are held by the manufacturer pending receipt of shipping orders from the Bureau. The Bureau of Ordnance shipping orders (BOSO) give detailed instructions as to what storage point(s) the materials are to be shipped, the method of transportation, and other pertinent information concerning the shipment. It is well to note at this time that under no circumstances may ordnance materials be transferred without issuance and receipt of Bureau shipping orders.

There are several categories of storage points for ordnance equipment (as well as other equipment) in the Navy supply system. Here again, their locations are determined by the Bureau so that they most efficiently serve the purposes for which they are designed.

RESERVE STOCK POINTS.—This type of supply point is designed to act as a reserve storage point. There are less than half a dozen within the continental United States. They are designed to contain BULK STORAGE. As new equipment is manufactured, the Bureau of Ordnance directs that it be sent to one of these points. There it will be stored until further Bureau shipping orders transfer it to other activities.

DISTRIBUTION POINTS.—In contrast to the reserve stock points, the distribution points are ready issue activities. The Bureau moves the bulk storage equipment from the reserve stock points to the distribution points as necessary. At the distribution points, the equipment is broken down from the original bulk condition into items of ready issue status. They will then hold this equipment until the Bureau issues shipping orders for its transfer to other facilities.

PRIMARY STOCK POINTS.—When equipment is transferred from the distribution points on Bureau shipping orders, it is sent to the primary stock points throughout the country as the need arises. These points are located normally at class A air stations. The class A air stations then supply their secondary dependent points and/or the operating activities with the aviation ordnance equipment they require. This type of transaction has to be performed in accordance with the allowance lists and current directives issued by the Bureau. It is not necessary for the primary stock points to obtain Bureau shipping orders to issue this equipment to the various operating activities it supports.

SECONDARY STOCK POINTS.—These stock points are located at class B air stations, outlying fields, auxiliary air stations, etc., and supply the service and operating squadrons with the aviation ordnance equipment they require. As with the primary stock points, the secondary stock points are governed by current allowance lists and directives promulgated by the Bureau of Ordnance.

Since the Bureau of Ordnance exerts complete control over all aviation explosive ordnance equipment, it is responsible for replenishment of the various stock points with this equipment. The Bureau has established a system of reporting which allows estimates of supplies of equipment needed to be furnished to the various stock points. Each quarter the primary stock points complete and forward to the Bureau a report of the stock on hand. From these reports, the Bureau is enabled to fill the requirements of these stock points. Replenishment is thereby automatically performed from the reports, relieving the primary stock points of the necessity of ordering. The Bureau draws the required material from the selected distribution point and sends it to the primary stock points concerned. The Bureau is not interested in the individual items furnished to the operating and service squadrons by the primary stock points. Items found to be in short or low inventory in the quarterly reports from the stock points furnish sufficient information upon which the Bureau may effectively base replenishment issues.

It is quite possible for the primary stock points to inadvertently miscalculate their needs due to unexpectedly heavy issues of certain items and for other reasons. When such an instance arises, they may forward an NTERIM REQUEST, used especially for this purpose, to the Bureau to rectify the situation. The needed materials are automatically transferred by the Bureau without waiting for the regular quarterly reports to accomplish the rectification.

The secondary stock points also perform the same type of reporting for purposes of replenishing their stocks. However, all such reports made are forwarded to the primary stock points instead of to the Bureau of Ordnance. In this way the primary stock points replensh the secondary stock points automatically each quarter. Interim requests originating at the secondary stock points are also forwarded to the primary stock points concerned rather than to the Bureau for replenishment of stock.

Aviation ordnance equipment, while still the major type of equipment with which the Aviation Ordnancenan is concerned, will not be the only type of stock class naterial utilized. This means that the aviation ordnance leading petty officer will have to be familiar with the process of ordering equipment from other stock classes, such as aircraft armament, found listed under the cognizance of bureaus other than the Bureau of Ordnance. It will be found that the supply of other classes of equipment will depend upon the policies established by the bureaus concerned. However, their supply disribution system will function similarly to that of the Bureau of Ordnance.

The Navy supply system is operated cooperatively beween the Bureau of Supplies and Accounts and each echnical bureau concerned. During World War II, it became evident that the technical bureaus had to develop a supply system to determine requirements, procurements, and distribution of increasing quantities of each specialized material required for the prosecution of the war effort. Each bureau had its own system and the results were that about 50 different systems grew up. Since none was standard and since items within each system varied from less than 100 items in one to nearly half a million in another, an early need for standardization was recognized.

Late in 1946, the Chief of Naval Operations adopted the current supply system based on three principles. Their principles are:

1. Logistic operations require both TECHNICAL and SUPPLY functions. Technical functions are peculiar to the specific type of material being supplied. Supply functions are equally applicable to all types of materials. Generally speaking, the Bureau of Supplies and Accounts is responsible for performance of the supply functions for Navy material. Each of the technical bureaus is charged with the performance of the technical functions for the material for which that bureau has technical responsibility.

2. The supply and technical functions for any category of material must be performed together. Material which must frequently be replenished is grouped into types and assigned to a SUPPLY OFFICE which is operated jointly as an activity of the Bureau of Supplies and Accounts and the technical bureau concerned. Supply offices (also known as supply-demand control points) have been established for aviation material, ship parts, ordnance, yards and docks material, electronics material, general stores, submarine material, and clothing and small stores.

3. A single revolving fund (the Navy Stock Fund) has been made the primary means of financing for replenishable material. The existence of a single fund permits coordination within the supply system. The Navy's annual appropriation can be charged with the cost of material only when the material is actually withdrawn from storage for use.

In actual practice, the system breaks down into three levels of material control. Top is the DEPARTMENTAL

LEVEL, at which broad policies are decided and performance of the whole operation is reviewed. Next, BUREAUS exercise detailed management control over the technical and supply functions. And finally, the third is the OPERATING LEVEL, consisting of supply-demand control points (supply offices) which actually do the work.

Those SUPPLY-DEMAND CONTROL POINTS, or supply offices, exercise Navywide inventory and distribution control over an assigned range of replenishable items. Each of these points is responsible jointly to a technical bureau for technical matters, and to the Bureau of Supplies and Accounts for business management. Also, each obtains its authority by delegation, either from its parent technical bureau or from the Bureau of Supplies and Accounts. The AVIATION SUPPLY OFFICE (ASO) is one of these supply-demand control points. It is under the joint administration of the Bureau of Aeronautics and the Bureau of Supplies and Accounts. A greater portion of its work is performed under delegated authority from the two bureaus. The Aviation Supply Office is charged with the determination of requirements, procurement, cataloguing, stock control, maintenance of records, and other supply functions concerning aviation armament equipment and other materials under the cognizance of the Bureau of Aeronautics.

It has been found that many of the functions originally performed by the Bureau of Aeronautics were duplicated within the activities of the Bureau of Supplies and Accounts. The Aviation Supply Office was formed and organized to eliminate as much of this duplication as possible. It took over the functions in which there were definite duplications such as cataloging, procurement, inventory control, storage, transportation, stores accounting, issue, and disposal. The Bureau of Aeronautics, however, did not delegate authority to the Aviation Supply Office in certain areas. The Bureau of Aeronautics, being a technical bureau, retained the function of procurement of NEW aeronautical material and equipment. It reasoned that this function was best performed by a technical bureau. Other technical bureaus such as the Bureau of Ordnance and the Bureau of Ships made certain reservation likewise to their own supply offices.

All of the technical bureaus generally function alike with regard to the Navy supply system. However, functions applicable to aviation supply concern only aviation materials which are under the cognizance of the Bureau of Aeronautics and the Bureau of Supplies and Accounts. The Bureau of Ordnance handles its ordnance materials in a different manner. This bureau has its own supply-demand control point, called the Ordnance Stock Office (OSO). Nevertheless, the Bureau of Ordnance retains direct control over ammunition, aviation ordnance under its cognizance, major ordnance items, and ordnance items of a highly classified and highly specialized nature. The Bureau of Ordance specifies the items over which the Ordnance Stock Office maintains control. Such items are generally spare parts, tools, and accessories. But, aviation ordnance equipment is only cataloged in this supply-demand control point. To make a comparison the Ordnance Stock Office performs functions for the Bureau of Ordnance comparable to those performed by the Aviation Supply Office for the Bureau of Aeronautics. Neither of these two supply-demand control points acts as warehouses. Actual storage and distribution take place at other activities. The storage and distribution facilities for aviation materials under the cognizance of both the Bureau of Ordnance and the Bureau of Aeronautics are similar and have previously been discussed.

Identification

Any information given at this time concerning class and stock numbers, Bureau of Aeronautics stock numbers, Bureau of Ordnance stock numbers, and other means of identifying the thousands of items embraced by the Naval Aeronautical Supply Organization would become obsolete "overnight" due to the federal cataloging program currently in full swing. A phase of this program is the conversion of the aeronautical supply organization to federal cataloging data. The aims and objectives of this program are to produce a "common language of supply." The benefits to be derived from such a program are expected to be increased military effectiveness, more efficient supply management, a strengthened government/industry relationship, and a sounder national economy.

The "common language of supply," which is a SINGLE LANGUAGE in this sense, aims to facilitate discovery and consolidation of duplicate items, interchange of supplies, standardization, reduction of inventories, reduction of storage space needed, and reduction of recordkeeping. In the past, each service developed and made use of its own classification, stock numbering, and identification policies. The resultant inconsistencies and differences have largely been eliminated by the federal cataloging uniform language of supply.

The main objective of the conversion program is to get all items used by all services under and identified by the federal stock numbers. These are eleven digit numbers. The first four digits denote the federal group and class. The remaining seven digits are usually referred to as the federal item identification number (FIIN). This number is serially assigned as the items are identified. Under the new classification system, the Bureau of Aeronautics and the Bureau of Supplies and Accounts will still have their Aviation Supply Office, and the Bureau of Ordnance will still have its Ordnance Supply Office. However, the stock classifying codes will have a "new look" as they will reflect the federal code rather than individual codes as before.

There are four types of stock numbers. They are the federal stock number, interim stock numbers, local stock numbers, and the coded federal stock numbers. The federal stock numbers do not have letters in their structures. (Example: 5305–105–5010.) Interim stock numbers are characterized by the letter "C" which denotes "centrally assigned." The letter C is used as a substitute for the first digit of the seven-digit stem. (Example: 5305–C00–0351.) Interim stock numbers will be assigned by the Aviation Supply Office. Assignment will be made only if the data required for obtaining a federal stock number are lacking when the material and/or supply documents are ready to enter the supply system, or if federal stock numbers were not available in time for conversion. Interim stock numbers are for temporary use only and will be replaced with federal stock numbers as soon as assigned. Local stock numbers are characterized by the letter L which replaces the first digit of the seven-digit system. (Example: 5305–L00–0003.) Items that are manufactured locally, locally procured materials, and other items carried by activities that are NOT system stock items will be assigned local stock numbers by the field activities concerned in accordance with the existing *Aviation Supply Office Instruction.* The Naval Aeronautical Supply Organization will use coded federal stock numbers, coded interim stock numbers, and coded local stock numbers at the time and after the system is converted as previously shown.

In addition to stock numbers, there are other identifying features to be found on ordnance equipment. Each piece of ordnance equipment is normally given a "mark" and a "modification" designation, a drawing number, and a piece number. These identifications serve, in addition to designating the actual item, to facilitate reference to the proper ordnance publications containing information relative to their construction, operation, maintenance, parts nomenclature, and safety precautions. Ordnance equipment may also be serially numbered to give individual identity to units that are physically similar. This serial number is stamped into certain ordnance equipment, or it appears on the nameplate together with the mark and modification numbers and other information. Serial numbers also facilitate identification of the manufacturer and place responsibility for custody. They are usually assigned to items of high unit value and to items subject to being stolen, such as small arms, etc. Manufacturers' catalogs may sometimes be used as a source of parts identification when other sources fail to produce identity. These catalogs should be retained when furnished with equipment.

It may be well to note while explaining that ordnance equipment is designated by "Mark" and "Mod," that ARMAMENT equipment is likewise designated by the term "Aero" and modifications added alphabetically, such as "Aero 1A" and "Aero 1B."

Procedures for Ordering Materials

Until such time as federal stock numbers have been assigned to all items, ordering will necessarily be more than normally complicated. After 1 December 1956, and until federal conversion of each conversion unit is completed, requests for materials will have to show both the Aviation Supply Office or Ordnance Supply Office number and the federal stock number. Also, each request for materials will be limited to one item per request. Catalogs used for references in requisitioning materials show a cross-index reference of stock numbers to simplify identification for ordering. The above procedure in ordering will facilitate processing and financial action for those documents in the "pipeline" subsequent to conversion. All documents in the "pipeline" which do not have current information as a result of the conversion will be changed to the proper stock numbers during normal processing operations. Documents initiated subsequent to conversion will indicate the federal stock number and the part number where readily available.

Almost all of the ammunition (explosives), ammunition details, and accessories are requisitioned from the Bureau of Ordnance by letter. Letters requisitioning any of the above ammunition are originated by commanding officers and directed to the Chief of the Bureau of Ordnance (or as directed otherwise by the applicable area commanders) in accordance with current instructions. Such letters are normally prepared by the gunnery officer and conform in style and content with regulations promulgated by the Bureau of Ordnance. The supply officer assigns a requisition number to each of these letters, but takes no further part in the preparation, submission, followup, etc. of these letters. Any and all materials obtained by letter request are accounted for by the gunnery officer.

Aviation Supply Office and Ordnance Supply Office stock is requisitioned by activities ashore on one form and on another by activities afloat. Issue of materials is not made without receipt by the issuing activity of the properly completed forms. This holds true, of course, for any issuing activity ashore or afloat. The word ISSUES, in supply terminology, refers to expenditures of materials from the supply department's custody to either shipboard use or to activities ashore.

There are a great many supply forms used in the issue and return of aviation ordnance and aviation armament materials. The proper ones to be used and the correct methods of completing these forms may be found in the *Bureau of Supplies and Accounts Manual.* Reference to this source of information should be made if there is any doubt as to the exact method to be used in completing supply forms correctly.

Use of Allowance Lists and Parts Catalogs

Allowance lists are set up by the various bureaus of the Navy for a specific reason. Long experience has shown the need for guides as to types and quantities of equipment and material to be carried on hand by the different types of naval activities. Locality, types of aircraft serviced, and many other pertinent factors are taken into consideration when setting up these allowance lists. When an activity is first commissioned, it receives a basic commissioning allowance of materials and then requisitions its own equipment and material needed subsequently in accordance with the allowance list set up by the appropriate bureaus. A knowledge of these various allowance lists will be of great advantage to any ordnanceman working in an ordnance storeroom or running an efficient ordnance shop.

All Bureau of Aeronautics Allowance Lists are issued in the form of sections. A complete listing of all these sections may be found in the *Naval Aeronautic Publications Index*, NavAer 00–500. In studying these allowance lists, it must be remembered that the quantities reflected therein are expected to cover a period of NINETY DAYS.

SECTION A contains standard aeronautical materials and is the allowance list for the commissioning and maintenance equipment that is common to all aircraft supported by carriers and tenders. Items such as valves, accumulators, and pumps are characteristic of this section.

SECTION B contains aircraft maintenance parts for specific aircraft models or series of models. This section allowance list is issued for each specific type of service aircraft and contains allowance of equipment needed for the maintenance of that specific type aircraft. All material is listed in the later Section B allowance lists by material classes.

SECTION G contains shop, hangar deck, and office supplies. It contains an allowance of drills, desks, lathes, file cabinets, etc. There is a section G allowance list for battleships, tenders, and cruisers; another for aircraft carriers; and a third for FASRons.

SECTION K contains publications and forms. These are all the publications and forms issued by the Bureau of Aeronautics and used by aeronautical activities.

SECTION O contains aviation armament material, arming and gunnery training materials. This section is of special interest to the Aviation Ordnanceman, as it sets forth allowances of armament material such as aircraft targets, tow reels and associated equipment, and bomb hoisting equipment.

SECTION P contains photographic material. All photographic material is under the control of the Bureau of Aeronautics. The Aviation Ordnanceman will find that all the gun cameras and related material are listed in this section.

SECTION U contains standard handtool kits. This section deals with the allowances of tool kits for various departments within different aeronautical activities. In addition to listing an allowance of tool kits, this section lists a breakdown of each kit.

Aviation ordnance allowance lists are published and issued as NAVORD LISTS. Of the many such lists, there are three of particular interest to the Aviation Ordnanceman.

NAVORD LIST 21416. This list issued by the Bureau of Ordnance, is likely to be somewhat confusing when first studied. It does not seem to be an allowance list in format. The reason for this is that this list merely gives a breakdown of types and quantities of parts found in each line maintenance and spare parts set. To find the complete sets allowance, reference must be made to NavOrd List 20870 (latest revision). NavOrd List 21416 may be used for an inventory check of complete spare parts sets.

NAVORD LIST 21486. This list contains aviation ordnance allowance for ships. Listing is made of such items as loading machines, bomb trucks, and allowances of other aviation ordnance handling equipment for all ships carrying and handling, or tending aircraft.

NAVORD LIST 20870. This allowance list, containing aviation ordnance for aircraft models, is the most important of all Bureau of Ordnance allowance lists. It contains allowances of aviation ordnance equipment for ALL service type aircraft. This list is divided into a number of tables which set up allowances for specific aircraft types. There is another definite use for NavOrd List 20870. Since it lists all aviation ordnance equipment for a specific type aircraft, it may be used as a handy and accurate inventory check list for each type of service aircraft.

Generally speaking, the PARTS CATALOGS issued by the Bureau of Aeronautics are of value to the Aviation Ordnanceman in maintaining armament equipment. These parts catalogs are to be found listed in the *Naval Aeronautic Publications Index,* NavAer 00–500, under Aircraft Armament Manual, 11 Series. The parts catalog prepared and issued for aviation ordnance is known as the *Illustrated Parts Breakdowns of Ordnance Equipment* (IPB). It is prepared by the U. S. Naval Ordnance Supply Office (OSO). Formerly, the parts listings now found in the IPB were contained in the *Catalog of Navy Material.* The *Index to Illustrated Parts Breakdowns of Ordnance Equipment,* IPB 0000, still lists items from the ORDNANCE SECTION of the *Catalog of Navy Material* as well as those items divorced from this latter publication. The Index also provides information on requisitioning and distribution policy for these publications. All future parts listings for SPECIFIC ORDNANCE EQUIPMENT will be issued by the OSO under the title of *Illustrated Parts Breakdowns of Ordnance Equipment.*

PUBLICATIONS, LOGS, RECORDS, AND REPORTS

The leading petty officer should invariably be familiar with all the publications, logs, records, and reports associated with administration, supply, ordering, and maintenance of aviation ordnance materials. He will constantly be called on to complete forms, originate reports, work up requisitions, and perform many other duties consistent with administration of an ordnance activity. Unless, or until, he has mastered the details of securing and maintaining publications, and properly completing logs, records, and reports, his value to his superiors and his ability to instruct the men under him are limited. Never will the Navy be free of "paperwork" any more than any other big business. It is a vital part of everyday administrative operations. The best that may be hoped for is that it may be reduced to an efficient and effective minimum.

Publications

It has been learned from experience that the average first class or chief aviation ordnance petty officer does not know, and is not familiar with, all of the publications dealing with the width and breadth of his rating. This is neither amazing nor limited to the aviation ordnance petty officer personnel. Such a great volume of publications exists which are directly concerned with each phase of endeavor that it is practically impossible for any one leading petty officer to become familiar with them all. Chances are that he may never even see all of them. Regardless of the above, the first class and chief petty officer should make it their explicit duty to become completely familiar with all of the publications dealing DIRECTLY with their work—expressly those dealwith their jobs as instructors and administrators. Other publications used less often and those dealing with secondary phases of their work should be obtained and perused to the extent that they are no longer "new" or "unheard of."

Obtaining all of the publications pertinent to a rating and/or the duties and responsibilities connected with an activity is most important. The commissioning allowance of publications will normally be short some items due to these being under preparation, under revision, or out of stock. These missing publications are back ordered and automatically forwarded to the activity as and when they become available.

Publications are vastly important to the successful operation of any operating activity. The activity having most of the pertinent publications and whose personnel know how to use them most effectively is the one which stands out above the average. An operating activity is entirely dependent upon the logistic system which brings the materials (over and above the commissioning allowance) and equipment used. How may this activity operate effectively if it does not have the knowledge or the means with which to requisition supplies properly? This knowledge is gained through the interim instructions and publications covering the conversion to federal stock numbers. It must be remembered that the ORDNANCE SECTION of the *Catalog of Navy Material* will be replaced by the card descriptions and electrical accounting machine cards of the federal cataloging system when conversion is completed. Personnel who intelligently employ all of these various media, through which supplies are procured and accounted for, place the activity to which they are assigned in an enviable position.

The Bureau of Ordnance as well as the Bureau of Aeronautics issues numerous publications prescribing necessary procedures for the operation and maintenance of specific ordnance equipment. The list of these can be found in the *Naval Aeronautic Publications Index.* A selected list of those having interest value to the aviation ordnance leading petty officers may be found in chapter 1 of *Aviation Ordnanceman 3 & 2,* Volume 1, NavPers 10345.

Some of the important publications issued periodically, which provide current information pertinent to the ordnance rate, are discussed here.

Naval Aviation News. The News is a monthly magazine of general and specific interest to all aviation ratings in the Navy. There is always a section of this magazine devoted to aviation ordnance alone. Current developments as well as helpful hints regarding work with aviation ordnance equipment are contained in this section.

Bulletin of Ordnance Information. This is a confidential publication issued quarterly. Many of the latest ordnance inovations are detailed in this bulletin. It should be read by all leading petty officers consistently.

Other publications from which valuable information and instructions may be gleaned are Department of the

Army and Air Force publications. Examples of these are such publications as Technical Manuals, Technical Bulletins, Field Manuals, Standard Nomenclature Lists, etc. There are also Navy training film catalogs which list many valuable training aids in the form of movies of various running times and subject areas. The leading petty officer will find many aviation ordnance subjects of value to project for the lower rates and strikers under his supervision, provided equipment and space are available for projection of these films.

Publications issued to the newly commissioned activity are automatically furnished via the Standard Navy Distribution List for Bureau of Aeronautics publications. Bureau of Ordnance publications are obtained in a different manner. Each newly activated squadron is responsible for securing its own commissioning allowance of publications from the Bureau. Applicable publications are listed in NavOrd OD 7012 (latest revision). As the leading petty officer may be called on to aid in the ordering of these publications, it is a good idea for him to become familiar with this publication.

There are a number of sources from which publications needed by an aircraft squadron have to be procured. All naval aeronautical publications are ordered from the *Naval Aeronautical Publications Index,* NavAer 00–500, by title and number on form NavAer 140. The properly completed form is sent to the nearest Bureau of Aeronautics publications supply point indicated in the inner cover of the Index. Selected aviation ordnance publications are also listed in the Bureau of Ordnance section of this Index, but should be ordered on NavSandA Form 43. This latter form is being replaced eventually by DD Form 1149. However, the bulk of ordnance publications are ordered through the use of the *Index of Ordnance Publications* OP 0. Nonregistered ordnance publications, such as Ordnance Pamphlets, NavOrd Instructions, Manuals, etc., are ordered by title or abbreviation on form DD 1149. Confidential publications are ordered on the same form but may not appear on a form containing nonclassified publications. They have to be ordered separately.

Requests for the Department of the Army publications not listed in the Index are forwarded to the Bureau of Ordnance as are requests for NavOrd Reports not listed therein.

Inventory management for forms and publications has been transferred from the Administrative Office of the Navy Department to the Bureau of Supplies and Accounts. Therefore, stocks and responsibility for the receipt, stocking, and issue of forms and publications in the Navy Central Publications Distribution System (NCPDS) has been transferred from the District Publications and Printing Offices to various stock points in the Navy supply system. Material formerly in the NCPD System and the Bureau of Supplies and Accounts distribution system has been assigned COGNIZANCE SYMBOL I for inventory management purposes. COGNIZANCE I FORMS AND PUBLICATIONS ARE THOSE DEVELOPED WITHIN THE NAVY AND BY OTHER GOVERNMENT AGENCIES WHICH HAVE WIDESPREAD USE ON A REPETITIVE BASIS THROUGHOUT THE NAVAL ESTABLISHMENT.

Aviation ordnance and aviation armament materials (publications) desired by an activity are ordered from three main sources. These are: First, Armament Manuals through the *Naval Aeronautic Publications Index,* NavAer 00–500 on form NavAer 140; second, Ordnance Pamphlets through the *Index of Ordnance Publications,* OP 0 on form DD 1149 (replacing NavSandA Form 43); and third, through the *Index of Forms and Publications,* Cognizance Symbol I, FPSO Inst. 5600.1 on form DD 1149. Materials not having widespread repetitive use, therefore not found in this latter Index, will have to be ordered from alternate sources. Form DD 1149 will be used for all Navy fleet units and shore activities to requisition cognizance I material, except submarines and submarine rescue vessels which are authorized to use form DD 1150.

Requirements of publications for various aircraft and miscellaneous type squadrons and groups are to be found in the *Publication Requirements List for Aircraft Activities,* NavOrd OD 7012 (latest revision). This is the basic requirements list of Bureau of Ordnance publications for aircraft activities. Department of the Army and Department of the Air Force ORDNANCE publications are also listed in this publication. The listings found in NavOrd OD 7012 are minimum requirements and in no manner restrict an activity as to the type of publication or quantity ordered. Listings in OD 7012 show the publication number, title, and minimum quantities required for all types of activities. Listed activities in this publication are such service, operating, and miscellaneous squadrons and groups as VP, VC, HAT, HATU, HS, FASRon, CVG, VS, VR, VU, VX, HU, ZP, VJ, ZX, VW, and comparable Marine Corps squadrons and groups. Leading petty officers should periodically check NavOrd 7012 to insure that the minimum requirements of ordnance publications are on hand at all times.

Logs, Records, and Reports

Administrative work in aviation ordnance is certain to involve the employment of logs, records, and reports. Any particular phase of aviation ordnance work requires that one or more of these items be utilized and correctly prepared. Ammunition, as an example, has to be LOGGED upon receipt, expenditure, survey, issue, surveillance, etc. RECORDS are continually being compiled on ammunition with regard to storage, shipment, issue, transshipment, condition, availability, survey, rework, carriers for, surveillance, testing and many others. From these records, and from other sources of information, it is necessary to originate specific REPORTS which go to the Bureau of Ordnance, the Naval Gun Factory, and other offices and technical bureaus. From the above it may be seen that the aviation ordnance leading petty officer, in his position of responsibility, will necessarily have to be familiar with many types of logs, records, and reports utilized in aviation ordnance administration. He will undoubtedly be the one who originates a great number of these necessary administrative details. His understanding of the details in the proper use of forms and his ability to make adequate records and formulate reports will enhance his ability and stature as a senior petty officer, leader, and instructor.

Ordnance forms for reports and records are found listed in NavOrdInst 5213.1. The standards for the design of report forms are found in the SecNavInst of comparable number. These instructions should be in the files of each activity. It is not practical to list in this chapter all of the various logs, reports, and records used in the administration of aviation ordnance. There are logs (rough and smooth) for materials received, work performed, receipt and expenditure of ammunition, magazine temperature and condition, and a host of other uses. There are probably more different types of reports and records made and kept than there are logs. In the final analysis, it is the responsibility of the leading petty officer to know the administrative records needed in his activity and to be able to properly employ them. Most activities have a prepared gouge from which the necessary reports and records may be determined, as well as their times of submission and to whom submitted. There are some 135 reports alone of a recurring nature required by the Navy Department from the various shore activities which concern ordnance. Roughly, some 38 of these recurring reports directly concern aviation ordnance, or are related thereto.

Of the current supply forms in use, the leading petty officer will find that two will be most extensively employed for requisitioning and returning supplies. These are the DD Form 1150 and the DD Form 1150A. Both are used as requests for issue or turn-in of material. They are issued in various colors and snapout copy combinations. The proper completion of these forms should be strictly a routine matter.

The Navy Directives Filing System

The Navy Directives System, which was placed in effect in July 1952, provides a uniform plan for issuing and maintaining directives. The System uses two types of directives, i.e., Instructions and Notices. These two directives have replaced many former types of publications. Publications of the Bureau of Ordnance alone replaced by these two directives are Ordnance Circular Letters (OCL's), Ordnance Material Letters (OML's), Ordnance Technical Instruction (OTI's), Ordnance Handling Instructions (OHI's), and Aviation Ordnance Modification Instructions (OHI-V's).

The Navy Directives System INSTRUCTIONS are directives of a continuing nature and are effective until subsequently canceled. The Notices are directives of a onetime nature, or directives which are applicable for a brief period of time (usually six months or less). Each Notice contains a provision for its own cancellation, for which a specific date is stated for record purposes.

The benefits derived from this System are manifold. Navywise use of the System enables each activity RECEIVING directives to effectively group them on any specific subject and relate directives on the same subject with other materials; have an easy method of filing directives and describing them as references; differentiate between directives of a continuing nature and those of brief duration; obtain copies of Instructions to replace lost or damaged copies, or obtain complete sets of instructions upon reactivation or commissioning; determine periodically, by use of Administrative Office quarterly check lists, the current status and completeness of the sets of directives; and determine, by the use of subject indexes, what directives are in effect on a subject.

Each activity which ISSUES directives is likewise benefited by the System in the following manners. Each issuing activity under the Directives System is able to: Reduce the number of directives in effect by consolidating Instructions which cover the same subject, by eliminating Instructions which duplicate, overlap, or conflict, and by promptly canceling obsolete directives; improve the adequacy and coverage of Instructions and identify gaps in policy and procedure so that directives can be issued to cover necessary subjects; eliminate duplicate writing, printing, and distributing operations; insure that recipients are sent only those directives which pertain to their operations; and finally, improve general administration by using a uniform system which includes reference aids for those receiving the directives.

Certain blocks of numbers are assigned, under the System, to specific subject groups. Whenever Notices and Instructions are written in a specific subject group, they are given a consecutive number (following a decimal after the basic subject group number) in the order in which they are produced. Thus, an Instruction written on GUN AMMUNITION, which carries the subject group number 8030, will be assigned the number 8030.1. If there is a subsequent directive on gun ammunition, it will bear the number 8030.2, etc. If the first Instruction is confidential, the number will be 08030.1; and if the second is secret, the number will be 008030.2.

Detailed information concerning the Navy Directives System will be found in the *Guide for Administration of the Navy Directives System,* NMOInst 5215.3 and *The Navy Directives System,* SecNavInst 5215.1A.

SALVAGE AND SURVEY PROCEDURES

Salvage is a method of disposing of equipment no longer needed or fit for use within an activity. The equipment is returned to a supply point for screening after the proper forms have been completed. Survey is a method of striking accountable materials from the books of the holding activity whenever such materials have been lost, destroyed, or when so directed by the cognizant bureau. A commanding officer may desire to secure replacements for the materials turned in for salvage or survey, or he may wish to receive credit for these materials. In order to effect an exchange of materials, or to receive proper credit for them, the currently employed survey and salvage procedures will have to be properly executed. Explicit form numbers will not be given in this chapter because new ones are about to replace the current forms used in requisitioning, salvaging, surveying, and accomplishing other procedures connected with aviation ordnance supply.

Surveys provide a record for an administrative review of the condition of the material, the cause of the condition, the responsibility therefor, and the recommendation for disposition. They also provide a record for an authorization to expend the material from the records on which carried and an authorization to decrease the monetary value of material in store.

There are two types of surveys, formal and informal. Each is performed in a different manner and each is required under different circumstances.

FORMAL SURVEY.—A formal survey will be made by either a commissioned officer or by a board of three officers with as many of these three being commissioned officers as practicable. In either instance the member, or members, will be appointed by the commanding officer of the activity concerned. In the event that sufficient commissioned officers are not available to the commanding officer to perform the survey under the regulations, he will submit the survey request for action to his immediate superior, or the senior officer present in case of the absence of his immediate superior.

There is a restriction as to the officers who may NOT serve on this type of survey. The commanding officer, the officer upon whose records the material being surveyed is carried, and the officer charged with the custody of the material being surveyed will not serve on the board of survey. A formal survey will be required for classes of materials or articles designated by the bureau or office concerned or when specifically directed by the commanding officer if the circumstances are considered to warrant such action.

INFORMAL SURVEYS.—This type of survey is made by the head of the department having custody of the material to be surveyed. The informal survey will be made in all cases when a formal survey is not required or directed by the commanding officer.

There are several phases which make up the survey procedure. First of all there has to be a request for survey. This request may be originated by any department, division, or section head, or even by a designated subordinate in accordance with regulations. The commanding officer then has to take action on the survey request. Next, the survey is prepared, after which the survey request is sent to the reviewing officer (usually the commanding officer) for action again. The final action consists of expenditure of the material from the records on which carried to Class 270 after recommendation by the survey report and approval by the reviewing officer.

Normally, the commanding officer submits the results of the survey to the bureau concerned for approval. However, he may direct immediate disposition of surveyed material PRIOR to the receipt of bureau approval if this action is considered necessary to safeguard the health or safety of his command.

When any person in the naval service is found to be culpably responsible by a survey officer, or board, the reviewing officer will refer the entire matter to such person for a statement. Further he will take the necessary and authorized disciplinary action, note on the survey the action taken, notify the Chief of Naval Personnel of the action taken, and, in the case of an officer, recommend to the Bureau that a statement to the effect be placed into the officer's record. Action on the survey with respect to the material involved will not, however, be held in abeyance pending disciplinary action. The conditions under which the above obtain are set forth in the *United States Navy Regulations,* Article 1953.

There are certain conditions under which a survey does not have to be made upon lost, damaged, or otherwise unserviceable material. If the cost per line item is $100 or less, and if such specific items as typewriters, etc., are not involved, expenditure may be made on a standard Bureau of Supplies and Accounts form. A notation worded "Loss by survey" must be provided on the form as an explanation as to the cause of the loss.

Regardless of whether or not the leading aviation ordnance petty officer looks forward to the prospects of performing administrative work, he will inevitably find that he is saddled with it to such an extent that a greater majority of his time will be spent learning and performing this type of work. In some ways his job will be comparable to that of a foreman or supervisor. He will constantly have to instruct the personnel for whom he is responsible; therefore, he should be a teacher. He will constantly have to prepare reports, letters, and instructions at his level of responsibility; therefore, he should be an administrator. He will undoubtedly have to come to the aid of those under him with regard to ethics, morals, adaptability, family life, and many aspects of administrative work; therefore, he should be a counselor.

One of the hardest phases of work for the first class and chief petty officers, especially the chief, is to be practically a full-time administrator and still find time to be completely current in the purely technical aspects of his rating. The tendency is to place emphasis on one of these two areas at the expense of the other. However, the leading petty officer who is able to keep himself current in both these areas is the one who will command the respect of those working with and under him. Strikers and lower rates are quick in their determinations as to the leading petty officers who know their "stuff" and those who do not.

QUIZ

1. Aviation ordnance equipment is manufactured under the cognizance of the
    a. Bureau of Ordnance
    b. Bureau of Aeronautics
    c. Ordnance Supply Office
    d. Aviation Supply Office

2. Aviation armament and ordnance equipment are held in bulk storage pending receipt of a BOSO at
    a. secondary stock points
    b. primary stock points
    c. distribution points
    d. reserve stock points

3. BuOrd authorization to ship equipment, in the form of a BOSO, is required from
    a. reserve stock points to distribution points
    b. distribution points to primary stock points
    c. manufacturer to reserve stock points
    d. all of the above

4. Those activities located at class A air stations holding equipment for issue are
    a. secondary stock points
    b. primary stock points
    c. distribution points
    d. reserve stock points

5. Stock control of aviation armament equipment is accomplished by the supply-demand control point known as
    a. Ordnance Supply Office
    b. Bureau of Ordnance
    c. Aviation Supply Office
    d. Bureau of Aeronautics

6. All aviation ordnance and armament equipment in the near future will be completely identified by
    a. Federal Item Identification Numbers
    b. Federal Stock Numbers
    c. Interim Stock Numbers
    d. Local Stock Numbers

7. Identifying features of aviation ordnance equipment may be
   a. BuOrd drawing numbers
   b. BuOrd piece numbers
   c. marks (Mk) and modification (Mod) numbers
   d. all of the above

8. All equipment allowance lists are expected to cover a period of
   a. 30 days
   b. 60 days
   c. 90 days
   d. 6 months

9. The allowance list that contains the allowances of aviation ordnance equipment for all service type aircraft is
   a. Section A
   b. Section O
   c. NavOrd List 20870
   d. NavOrd List 21486

10. That publication containing general interest information of value to all hands in aviation is
   a. *All Hands*
   b. *Naval Aviation News*
   c. *Navy Department Bulletin*
   d. *Bureau of Ordnance Information*

11. Publications and forms having widespread use in the naval establishment may be ordered on
   a. DD Form 1149
   b. DD Form 1150
   c. NavSandA Form 43
   d. NavAer Form 140

12. Allowances of ordnance publications and forms for aircraft activities may be found in
   a. NavOrd OD 7012
   b. NavOrd List 21416
   c. Section O
   d. Section K

CHAPTER 12

TRAINING AND SUPERVISORY TECHNIQUES FOR AVIATION ORDNANCE

According to the dictionary, TECHNIQUES ARE THE METHODS OR THE DETAILS OF THE PROCEDURES ESSENTIAL TO EXPERTNESS OF EXECUTION IN ANY FIELD. Fields of he arts and the sciences are examples. Therefore, techniques are the manners of performance with reference o such expertness. In simpler words, a technique is a special method or procedure used to do something. And to do this something well it is essential that the technique employed is a GOOD one. The windup of a baseball pitcher may be such that his rhythm is poor, causing him to "balk" occasionally; thus he may be said to have a bad windup technique, or a bad pitching technique. The Aviation Ordnanceman, who consistently handles dangerous munitions exactly in accordance with the ime-proven methods which have fostered the greatest afety, may be said to have a good technique in handling munitions. Leading aviation ordnance petty offiers must employ various techniques in their training and supervision of the men under them. They may have acquired these techniques in formal training schools, or hey may have picked them up through necessity by experience since their striker days.

Regardless of how they were attained, techniques are essential in the effective and proficient training and supervision of the men. If a leading petty officer will evaluate himself on how effective he is using the various techniques he has learned through the years, he will have a pretty good idea of how valuable he is to the Navy.

Why is it that some leading aviation ordnance petty officers make better instructors and supervisors than others with equal time in the Navy? There are several reasons. It will be found that some of these men have a natural flair for teaching and an innate ability to supervise men. Others do not. Some will have had more experience in supervision and instruction than others due to the nature of their past billets. And then there is the fact that some actually enjoy teaching and supervising while others have not developed these traits. However, it has been found that practically any intelligent person may become a proficient instructor and supervisor provided he receives proper training, either from schooling or personal experience as has been previously stated.

There are today many first class and chief aviation ordnance petty officers doing excellent jobs in the Navy who have acquired their excellence in these two areas through personal experience alone. These petty officers have gotten where they are through reading, self study, closely observing the effects of their supervision and instruction on the men placed in their charge, changing their techniques when found ineffective, and generally keeping an alert and open mind regarding responsibilities as an instructor and supervisor.

The first class and chief aviation ordnance petty officers are respected throughout the Navy for their ability to handle and supervise the handling of aviation explosive ordnance with the maximum of safety. Such respect has not been easily gained. It has taken a lot of thought, study, planning, manual labor, and an unsurpassed attention to details on the part of each of these petty officers to have eventually earned this respect. Each formulated his own plans of action, took direct steps to insure that the plans were explicitly carried out, and exercised great pains to treat the men under him with fairness, equality, and consideration.

Supervision and training may be said to run hand-in-hand. Hence, supervisory and training techniques may be considered to do the same. In almost every type of naval activity, the leading aviation ordnance petty officer will routinely perform the duties of training and supervision concurrently. Both of these elements dovetail so completely that where one starts and leaves off can hardly be distinguished from the other. A first class petty officer giving instructions on the details of disassembly and reassembly of a 20-mm aircraft gun not only instructs the men but supervises their efforts as well. Although supervision and instruction and their related techniques are closely allied, they will be discussed separately in this chapter.

TRAINING TECHNIQUES

There have been a great many educational publications written by the services and civilian educators dealing with training and supervisory techniques. Some of these publications cover the entire field of education, while others cover only certain phases, such as the techniques of training and supervision. A leading aviation ordnance petty officer will experience little difficulty in procuring the exact references which cover the fundamentals and/or the details of supervision and training. A partial listing of such references may be found in chapter 1 in the subsection entitled, "Practical Leadership." In most cases, these may be obtained from your Information and Education Officer. Due to the fact that there are available such a number of excellent reference materials from which the leading petty officer may learn the principles of supervision and training, this chapter will only briefly discuss these techniques. Further, the discussion herein contained will deal with these techniques only from the standpoint of how they apply to aviation ordnance.

Paralleling the changes in supervisory and training techniques which have taken place over the past few years, there have been other changes in the broader phases of education. With today's specialization in all fields, the trainee is more apt to be taught, or to learn, those things which apply to his specialization directly.

Aviation Ordnance Leadership

Leadership is the art of influencing human behavior, or the ability to handle men. Aviation ordnance leading petty officers began developing this art from the time they were given their first responsible job as rated men. It may have been an unconscious effort on their part, or they may have actually realized that they were beginning to develop certain leadership qualities. Now that they have become leading petty officers, they seek to perfect their techniques, knowing full well that specific techniques are essential to effective training and supervision. The culmination of all their efforts towards becoming proficient teachers and supervisors SHOULD be reached usually by the time they become first class and certainly by the time they become chief. Since the greater share of the work performed by these leading petty officers is concerned with training and supervision, their work must be highly effective to properly discharge their duties to the Navy.

In order to become really worthwhile as an aviation ordnance instructor or supervisor, it is necessary to have and exhibit marked qualities of leadership. A leader, in the full sense of the word, first of all insures that the mission of his task is satisfactorily completed. Then, and only then, does he carry out his duty to his men for whom he is responsible. This may seem a little hard and even inhuman at first glance. However, let us suppose that a fighter group has just returned from a mission. The leading Aviation Ordnanceman with his men had rearmed and replenished these same planes not too long before. Again the guns have to be checked and rearmed and other armament stores of the aircraft replenished in a minimum of time so that they may become once more airborne. The actual safety of the ship and all hands aboard may easily depend upon getting these aircraft back in the air for protection as well as to carry out other missions.

The chief petty officer (or the first class) having charge of this work knows that his men are almost completely exhausted from lack of sleep, extreme physical exertion, and insufficient food. His mission, therefore his primary task, is to get the fighter group rearmed and ready for launching. He sees to it that his work is accomplished IN SPITE OF THE CONDITION OF HIS MEN, paying particular attention to details which may have been overlooked by these tired men. As soon as this work is successfully completed, the petty officer in charge then concerns himself with the desires, needs, and mental states of his men.

The leading petty officer exhibited true leadership qualities in the above instance. The reason that he was able to get this important work accomplished in spite of the condition of his men was that they knew that he was completely fair in his demands. They knew that he would expect nothing from them beyond the work which was essential to the completion of the mission at hand. Also they knew that he would, at the very first opportunity, take care of their needs and welfare in general. Competent leadership such as exhibited in the above example has had a large part in making the Navy the tremendous well-organized fighting force it is today.

Military leadership, like any other form of leadership, requires that certain factors or elements be exhibited to make it a vital and driving force. The leading aviation ordnance petty officer by virtue of his position must demand discipline from his men. His tolerance to undisciplined actions on the part of his men actually marks him as a poor leader in their eyes although he may not realize it at the time. The morale of the men under him is of vital importance to the leading petty officer. Only when his men exhibit zeal in their work, have pride in the accomplishment of their work, evidence confidence in their leading petty officer, show a healthy mental and emotional state of mind (known as esprit de corps), and possess efficient work habits is the aviation ordnance leading petty officer certain that his leadership is of the highest quality.

Another element directly connected with the art of leadership is that of ethics. Ethics is thought of in this connection as the exercise of duty of obligation along moral lines. The leading aviation ordnance petty officer must have developed a strong sense of what is right and wrong by the time he reaches leading petty officer status. His ability to stand staunchly by his convictions concerning correct moral ethics, sometimes in the face of poorly concealed disbelief of his men, is a factor which will ultimately win his men's confidence.

By sticking to a high standard of honor and integrity, he will not only win the confidence of his men, but also that of his superiors. As an example, there may be a time in which the men of a target marking detail might apply great pressure to the leading petty officer in charge of the working party to mark the targets "to our favor" in order to win a coveted gunnery trophy. The leading petty officer clearly understands that such a procedure would be morally incorrect and unethical. What does he do? He tosses out all the "probables" and questionable marking on the banner target and counts only those which may be substantiated. It might be that he would have gone completely undetected if he had chosen to follow his men's request. As it was, the men growled loudly at his decision. But in the final analysis, they had a great deal more respect for him than if he had let them get away with something dishonest. They even bragged about what a "square shooter" he was to one another, and, later on, to others entered in the same competition.

A leader among men invariably possesses certain traits which have caused him to become a leader. He may have gained a number of these important traits without his becoming aware of the fact; many of them being inherent to his character. The aviation ordnance leader is DEPENDABLE. If he tells his men that he will go to the captain with a request for more adequate locker space, or any other request within reason, he will do just that. What he says he will do, he does. If he should happen to be completely blocked in his efforts, he is careful to explain without hedging what has been done and why he did not succeed. The aviation ordnance leader is COURAGEOUS both physically and morally. He will tell his men that a certain practice is not morally right and will see to it that the practice is stamped out. He offers a morally correct practice in lieu of the other and insures that it becomes a routine matter thereafter. Most men are not born with a vast supply of physical courage. They have to condition themselves so that when the necessity arises, they will act in a courageous manner without giving too much thought to the matter. A live bomb hung in the bomb bay of a returning aircraft has to be quickly and safely removed and unarmed. The leading aviation ordnance petty officer in charge personally aids in and directs the removal of the dangerous store. It is simply not in his makeup to ask his men to perform a dangerous act that he would not undertake himself.

TACT is outstanding among the traits of an aviation ordnance leader. He does not allow himself to give offense to his men any more than he would to his superiors. Why should he call a third class petty officer a "jarheaded stumblebum" for missing the point of instruction he previously gave. He obtains vastly more favorable response from the petty officer by talking to him and pointing out wherein he erred and indicating how or what he should have done. Tactlessness breeds contempt and anger. The leading petty officer inherently knows this and acts accordingly.

There are many other traits common to a recognized leader. They are all important characteristics and complement each other in the same manner that certain colors are complementary. The remaining traits and characteristics inherent to an aviation ordnance leading petty officer are unselfishness, alertness, sympathy, military bearing, strength of will, decisiveness, loyalty, endurance, justice, enthusiasm, keen judgment, humility, integrity, initiative, and finally, humor. Even the best leaders may not possess all of these qualities in their fullest meaning, but all leaders DO possess ALL of these traits to a marked degree.

Effective Instruction

In order for the leading aviation ordnance petty officer to give the most effective instruction to the men under his supervision, he must do a lot of planning on the type and kind of instruction to be used and employ all available instructional aids and demonstration models. If, for instance, he is to give instructions which deal with the firing of small arms, he should plan the instruction logically step by step and lay particular emphasis on the trigger squeeze technique. This is an all-important technique in effective shooting. Regardless of the time spent at lecture on the technique of the trigger squeeze, little will actually be gained unless and until the student has had a chance to practice this procedure on the real weapon. The same is true of the sighting technique and others. The advisability of using instructional aids and demonstration models cannot be overemphasized whenever the actual piece of equipment is not available or is totally unfit for classroom use due to size, cost, or complexity. At times, however, demonstrations may be made clearer through the use of models than with the actual equipment. This is especially true in instances involving giving instruction to large numbers of men simultaneously. They will all be able to see the model when properly displayed, whereas they might not all be able to see the actual piece of equipment clearly enough to observe the details.

The first step in setting up an effective instruction program in any field is PLANNING. Planning for instruction in the technical fields is not desirable—it is mandatory. Since everything concerned in the aviation ordnance rating is of a highly technical nature, it is evident that thorough planning for instructions to be given cannot be slighted in any sense. Just as it is foolhardy to attempt construction of an intricate piece of ordnance equipment without specifications, it is also foolhardy to attempt explaining the operation of elements of a bomb director system to trainees without the proper planning and employment of the correct instructional aids and models. Each lesson or increment of the total instruction has to be planned precisely in advance. If such is consistently accomplished, learning becomes easier and infinitely faster for the trainee.

The instructor performs his job much more precisely and the student learns more quickly and accurately when the instruction is offered in a logical sequence. For this reason, a lesson plan is needed which sets down the various steps of instruction. The leading aviation ordnance petty officer cannot afford to trust to memory while explaining the procedures of checking the bombing system of an attack aircraft with its associated testing equipment. He must have at his disposal a lesson plan prepared earlier which notes in detail the various steps. It does not matter whether he is giving instruction on the correct method of boresighting turret guns or lecturing on the deterioration of dunage materials at advanced bases.

Methods of Instruction

Three commonly employed methods of instruction are the LECTURE, the DISCUSSION, and the DEMONSTRATION. Each has its advantages and disadvantages. Quite often one or more of these methods may be combined to advantage in certain types of instruction, or instruction on certain equipments. In other instances, one of these methods may work better if employed by itself. However, too much dependence should not be put in any one of these methods working well for all occasions. The lecture method is considered to be the least effective of the three for most purposes.

The leading aviation ordnance petty officer, when instructing a large class, may benefit in certain instances by using the lecture method. For example, in telling how gases of combustion operate the mechanism of the M1 Garand rifle, a short well planned discourse, with charts and diagrams, may serve admirably to get this information across to the students. However, learning, in this instance, will be greatly improved if, after the lecture, the petty officer gives an actual demonstration of the weapon so that the students may correlate what they have heard with what they have seen.

A large portion of the teaching performed in the Navy is accomplished through the DISCUSSION METHOD. This method requires student participation to a degree not found in the other methods, and for that reason is a much more effective method of instruction.

The leading aviation ordnance petty officer will find this method a great help in getting across to a class, or informal group, the knowledge necessary to safely and effectively install various types of nose and tail fuzes in aircraft bomb stores. By commencing the session with a brief summary of what is to be learned, the instructor sets the stage for utilizing the discussion method of instruction. He will now create student interest by drawing out automatic answers to his carefully planned questions on the topic. The leading petty officer never calls on his students in any set pattern, but at random. This procedure keeps the trainees more alert as they are never certain when they may be called on to answer a question.

The DEMONSTRATION METHOD of instruction is probably the most effective method known whereby trainees learn exact methods of performance in technical work. This method succeeds where others fail at times, because it attracts the attention of the trainee, thereby arousing his direct interest. Trainees will WANT to try their skill at doing the job.

The demonstration method may be used most effectively in teaching principles of operation, maintenance, testing, inspection, and other phases connected with aviation ordnance equipment and methods of operations. Ordnance leading petty officers find this method excellent, for example, in training the lower rates and ordnance strikers how to make various correct switch settings in the bombing, rocket, and other stores circuits of the particular aircraft with which they are concerned. The instructor adeptly makes the proper setting for a given load of stores to be expended and then requires each trainee to perform the same functions in exactly the same order. The instructor may even have available mockups of stores systems with which to demonstrate all of the various loading configurations possible for the aircraft concerned. Through demonstrations either with the mockup or the actual aircraft, the instructor is enabled in the shortest time to insure that his students are capable of performing the required work.

Learning and Learning Processes

The instructor's role in the learning process is to expedite the learning by causing it to take place in the trainee's mind more effectively and in a shorter period of time. It will be found, however, that there are certain learning processes which take place in the mind of the trainee without benefit of instructor guidance. Examples of these processes are the methods of trial and error, observation, transfer, and learning by doing.

The TRIAL AND ERROR method lends itself to waste of time and energy with respect to learning. The period of learning under this method is necessarily longer than under guided instruction. Once an error is made in the learning process, progress halts and a complete new start has to be undertaken. It would be grossly negligent to allow a trainee to attempt repair of a delicate and costly piece of ordnance gear if he had never had his hands on it before. It might even cost him his life as well as that of others nearby. Of course, proper instruction prevents the trainee having to learn under the trial and error method, so this method has no place in the Navy training system.

Learning by means of OBSERVATION is infinitely better than trying to acquire knowledge by trial and error. However, there are a number of drawbacks to this method. Even when CLOSELY observing an experienced man perform a piece of work, many of the finer points as well as some of the basic points of the performance will surely be missed by the observer. He simply cannot observe them all; there is too much to be seen. A Third Class Aviation Ordnanceman watching an instructor consistently hitting the bull's-eye on the 200-yard rifle range will probably see only that. He will undoubtedly miss seeing how carefully the instructor squeezes the trigger of the rifle, will most likely not notice how the sling is fitted to his arm, and, of course, will be absolutely unable to see the alignment of the front and rear sights with the bull's-eye. How will the trainee be able to learn proper rifle shooting techniques if all he sees is the consistent hitting of the bull's-eye? It is obvious that he cannot. He must have the techniques explained to him as the performance progresses or prior to commencement of the performance so that he will KNOW WHAT TO LOOK FOR and UNDERSTAND WHAT IS GOING ON even though he is not able to see it all. And then he must practice all phases of the performance himself.

Learning by TRANSFER may be likened to the reuse of previously gained knowledge in new situations. The man who previously learned to measure clearances between switch contacts and to "regap" sparkplugs would not be at a total loss to know how to measure the headspace in a .50 caliber aircraft machine gun. He would be able to transfer some of his earlier learning to the new situation. The measuring components with which he previously worked and those he now attempts to use have something in common. Therefore, it may be said that the transfer of common components may take place in learning situations. It may easily be seen, however, that the student in this case has only a "smattering" of the knowledge of measuring and will not be able to accurately measure the headspace of the gun.

One of the most expeditious and effective methods of learning is that of EARNING BY DOING. This is not a self-teaching method; it requires that the instructor's services be utilized. The instructor and the trainee must work closely together. Learning takes place under this method in the following manner: The instructor first performs what is to be done and tells the trainee what he is doing while he works. Next, the trainee attempts to tell what is being done while the instructor once again performs the work. It now becomes the trainee's turn to perform the work and tell at the same time what he is doing. Finally, the trainee practices what he has learned while the instructor closely supervises the work.

It is easily guessed from the above that learning by doing is the basic method for most types of on-the-job training in the Navy. The leading aviation ordnance petty officer has a relatively easy time teaching an aviation ordnance striker how to field strip a .45 caliber automatic pistol using the learning-by-doing method of instruction. Conversely, it is relatively easy for the striker to learn fieldstripping of this hand gun in a minimum of time by working with the instructor under this method.

Conditions, Attitudes, and Habits

Many factors affect the manner in which the trainee's mind will absorb learning and the learning process. The PHYSICAL CONDITION of the men under instruction is a major consideration in determining their ability to learn. It is reasonably certain that a discussion conducted by an instructor on the overrun mechanism of a gun camera would be something less than successful under adverse conditions of temperature, lighting, noise and other distracting elements.

The alert instructor will invariably think of and do something about the mental conditions and conditioning of his trainees. He has to know how to cope with the various types of mental distresses and take positive action to remedy them. His approach to the problem should be from a sympathetic angle rather than one of rebuff or anger.

A good example of this is the instance in which a Chief Aviation Ordnanceman, employing the teaching-by-doing method, was instructing a class in the reassembly of a 20-mm aircraft gun. A First Class Aviation Ordnanceman was monitoring the class composed of lower rates and strikers. In the course of telling the class what he was doing, the Chief called on the First Class, asking him to select the next part to be assembled and to place it in the gun receiver in its proper position. The First Class, hesitating momentarily, picked up the wrong piece and tried without success to fit it into position. His embarrassment was pathetically evident.

The Chief, seeing a chance to drive home a point, made comment to the class that the incident showed the importance of continued practice to the perfection of a process or an ability. This did nothing to ease the embarrassment of the First Class. When a student attempted to make a joke of the situation, the First Class' embarrassment turned quickly to anger, and he stalked out of the classroom leaving a perplexed instructor and a chorus of guffaws. Immediately after class the instructor looked up the First Class and cautiously began to question him. His sympathetic approach eventually turned up the fact that the First Class has been denied leave due to the heavy teaching schedule. He earnestly desired to ease the strain under which he had been working by going hunting. His division officer felt that his services could not be spared at the time. The Chief "went to bat" for the First Class and got his leave approved. Had the Chief been merely resentful or angered by the incident and severely reprimanded this petty officer for his mistake and lack of control instead of approaching the situation sympathetically, the results may have been totally different. As as it was, the petty officer returned from his leave with an entirely different mental attitude towards the Chief, the trainees, and his work, and with a readiness to attack his arduous duties with renewed vitality.

The leading aviation ordnance petty officer should assign his students specific "home work" when time does not permit all of the technical data to be adequately covered in regular study periods either ashore of afloat. He should test the men periodically on this outside work to insure that they understand what they accomplished on their own. If, for instance, the subject being covered is the electrohydraulic turret, he might assign outside reading in the basic electricity and hydraulic handbooks to cover some of the basic theory, and cover other areas of theory and all possible practical work in class. By questioning the trainees during the study periods and giving tests covering the areas assigned in the collateral reading, he may check on their STUDY HABITS and their total progress. The leading petty officer must constantly review the basic concepts of good work habits and study habits with the trainees so that, through repetition, they will become second nature to the greatest extent possible.

PRINCIPLES OF SUPERVISION

Article 1210 of the *United States Navy Regulations* states in part that Navy petty officers "shall aid to the utmost of their ability, and to the extent of their authority, in maintaining good order and discipline, and in all that concerns the efficiency of the command." This is a major responsibility of the petty officer. It is likewise a major duty. To accomplish these conditions of the *Regulations* as a leading aviation ordnance petty officer and supervisor, it is necessary to direct the activities of the men being supervised in such a manner to cause them to have pride in jobs that they have performed well. Further, in order to direct activities competently, it is necessary to have a working knowledge of the principles of supervision. Supervision consists of the exercise of good common sense and judgment; the application of certain basic principles; an understanding of human nature to the greatest extent possible, and ability to make decisions; a practice of impartial treatment to all; and an intense loyalty to both superiors and the men being supervised. By the time that an Aviation Ordnanceman becomes a leading petty officer he has already developed many, if not all, of these attributes, and needs merely to concentrate on those few that he has not entirely grasped.

Duties and responsibilities of the leading aviation ordnance petty officer run hand-in-hand. He has certain areas of RESPONSIBILITY that are inherent to the nature of his work and to his rate as a petty officer of the Navy. His DUTIES lie to a great extent in accomplishments in the areas of work for which he is responsible. This petty officer must be a military leader and a technical man at the same time. These functions are also closely related. He may not work at one to the exclusion of the other and vice versa. The leading petty officer MUST know the technical aspects of aviation ordnance or his usefulness as a supervisor and as a technical man is severely curtailed. He must have the attributes of a good military leader, otherwise his usefulness as a supervisor and leader is equally limited. Thus, he is definitely limited in the fields of leadership and supervision as well as in his usefulness to the Navy if, for instance, he is unable to explain the operation of a particular piece of ordnance equipment, or is unable to effectively supervise a working party handling ammunition.

A supervisor by definition is one who is responsible for and directs the work of others. This means that the aviation ordnance leading petty officer has to actually oversee and instruct the men under his supervision. A mere inspection of the nature of the duties of the men under him is NOT supervision. The function of supervision is not considered to have been fulfilled until positive action has been taken to improve a program, to expedite a process, or to otherwise improve a given situation. The supervisor has a tremendous job when all facets are considered. He must satisfy the demands of his superiors, he must keep his men busy and happy in their work, and, as a check on himself, must constantly analyze his abilities in the job and whether or not he is successfully accomplishing the goals of an instructor and leader.

Personnel Relationships

The everyday contacts of the supervisor with the men under him and others associated with him constitute personnel relationships. The aviation ordnance leading petty officer is not so much concerned with the everyday contacts as he is with what he can do to maintain and improve good personnel relationships. He realizes, of course, that when the men under his supervision are generally satisfied with their working conditions there must be in existence in the activity a sense of good personnel relationships on a continuing basis. He also realizes that the manner in which he personally handles his own contacts is a major factor in how he is liked and how his supervision is taken by his men. It matters not whether these contacts are on a group or an individual basis. It requires just as much tact, interest, enthusiasm, and effort in making one working contact as in making many at one time.

If the leading aviation ordnance petty officer has not already learned that an irritating and threatening manner of making personal contacts tends to sever otherwise good relationships, he should only have to be TOLD this fact to become a believer—he should never allow himself to make such a test. He should remember one fact in particular—that the discharge of an instructor's entire set of responsibilities lies in the manner in which he handles personnel. Effecting good personnel relationships constitutes a greater portion of the responsibility and duty of a supervisor and military leader.

One of the factors influencing the supervisor's ability to maintain good personnel relationships is his manner of giving orders. Quite often there is a failure on the part of the supervisor to note the close connection existing between discipline, cooperation, and giving orders. It will be found that discipline built entirely upon fear cannot last. Sooner or later it crumbles. Orders given in connection with military drill, etc. should invariably be given in a clear crisp voice devoid of excitement and slowly enough for their meaning to be clearly understood. Orders given to a trainee, or group of trainees, by a supervisor normally take the form of directions, assignments, requests for performance of certain work to be accomplished, and others of like nature. The only military implication in these orders is that of obedience on the part of the trainee. Otherwise, there is little similarity in the two types of orders. However, the supervisor must exhibit consideration in any type of order he gives. He must have the military and supervisory qualities that will enable him to carry out his duties and responsibilities in the most advantageous manner and to see to it that his subordinates do likewise.

Qualities of a Good Supervisor

To attain the status of a good supervisor one must possess a number of qualities and traits which directly and indirectly have their effect on the men supervised. A definite relationship exists between the supervisor, the instructor, and the leader. Each might be said to occupy one point of a triangle, so closely are they related. The traits and qualities normally attributed to the good supervisor are equally applicable to the good instructor and the good leader. They all employ the same techniques and adhere to the same principles in a broad sense. By the time that the leading aviation ordnance petty officer becomes qualified as a good supervisor, he has also attained the good qualities and traits of instructing and leadership.

It is neither feasible nor desirable to detail in this course all of the traits and qualities intimately associated with the good supervisor, instructor, or leader. However, it is important that the leading aviation ordnance petty officer, through self-appraisal, constantly remind himself of these traits and qualities in order to maintain and improve his value to the Navy. A good review of supervision, instruction and leadership may be found in chapter 3 of the *Military Requirements for Petty Officers 3 & 2,* NavPers 10056, and pertinent sections of the *Manual for Navy Instructors,* NavPers 16103–B.

QUIZ

1. All aviation ordnance leading petty officers are capable of instructing or supervising personnel because of
   a. natural ability
   b. personal experience
   c. proper training
   d. all of the above
2. The first duty of an aviation ordnance leading petty officer as a leader is to
   a. demand discipline among his men
   b. attend to the needs and welfare of his men
   c. insure satisfactory completion of his mission
   d. insure a high state of morale among his men
3. Of the three commonly employed methods of instruction, the LEAST effective is
   a. lecture
   b. discussion
   c. demonstration
   d. none of the above
4. A large portion of the instruction performed in the Navy is accomplished through the
   a. lecture method
   b. discussion method
   c. demonstration method
   d. trial and error method

5. To teach a trainee thoroughly, detail stripping for cleaning a machine gun would probably require use of both the
   - a. lecture and demonstration method
   - b. lecture and discussion method
   - c. discussion and trial and error method
   - d. discussion and demonstration method

6. A learning process not requiring the benefit of an instructor's guidance is the
   - a. trial and error method
   - b. observation method
   - c. transfer method
   - d. all of the above

7. A learning process requiring the presence of an instructor is the
   - a. trial and error method
   - b. observation method
   - c. learning by doing method
   - d. transfer method

8. A close relationship exists between
   - a. discipline and giving orders
   - b. giving orders and cooperation
   - c. cooperation and discipline
   - d. all of the above

9. The factor(s) affecting the receptivity of the trainee to learning are/is his
   - a. mental state of mind
   - b. physical condition
   - c. overall outlook
   - d. all of the above

10. Leadership of the highest quality is evidenced by the men under supervision and instruction when they
    - a. show a healthy mental state of mind
    - b. exhibit confidence in their leading petty officer
    - c. have pride in the accomplishment of their work
    - d. all of the above

11. The leading aviation ordnance petty officer will perform the duties of training and supervision
    - a. separately
    - b. by training first, then supervising
    - c. concurrently
    - d. by supervising first, then training

12. Some aviation ordnance leading petty officers have greater success as instructors than others because they
    a. enjoy teaching and supervising
    b. have a natural flair for teaching
    c. have had more experience due to nature of their past billets
    d. all of the above

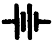
13. The most effective instruction to the men is afforded by the instructor's
    a. use of the lecture method
    b. employment of all available training aids and demonstration models
    c. disregard of the individual trainee
    d. none of the above

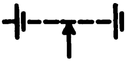
14. The leading aviation ordnance petty officer's major responsibilities and duties are set forth in the
    a. *Bureau of Naval Personnel Manual*
    b. *Bureau of Ordnance Manual*
    c. *United States Navy Regulations*
    d. *Bureau of Aeronautics Manual*

APPENDIX I—ELECTRONIC PARTS SYMBOLS

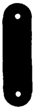
BATTERY

ONECELL


MULTICELL

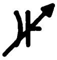

TAPPED MULTICELL

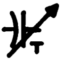
(LONG LINE IS POSITIVE)

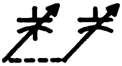

BUS

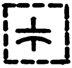
CAPACITOR

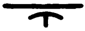
FIXED


VARIABLE

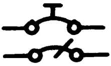

TRIMMER


GANGED

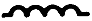

SHIELDED

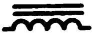

FEED THROUGH

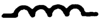
(WHEN ELECTRODE IDENTIFICATION IS NECESSARY, CURVED ELEMENT REPRESENTS OUTSIDE ELECTRODE OF PAPER AND CERAMIC UNITS, NEGATIVE OF ELECTROLYTICS AND LOW POTENTIAL ELECTRODE OF FEED THROUGH.)

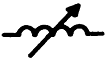

CIRCUIT BREAKERS

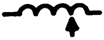
COIL


GENERAL

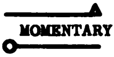

MAGNETIC CORE

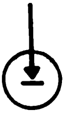

TAPPED


ADJUSTABLE OR VARIABLE

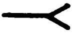
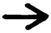

ADJUSTABLE

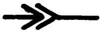
CONTACTS


MOMENTARY

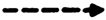

FIRING PIN CONTACT

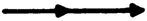
CONNECTOR



FEMALE MALE
PIN CONTACTS


ENGAGED
PIN CONTACTS

CONNECTIONS

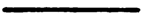
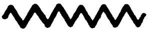

MECHANICAL

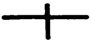

ELECTRICAL

CONNECTIONS

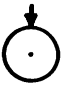
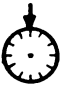
PATH

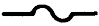
CONDUCTIVE

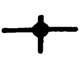
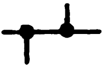
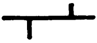


AIR OR SPACE


NO CONNECTION

DIALS

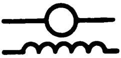

OR



FUSE

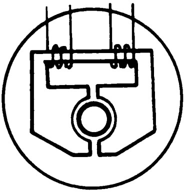




GROUND

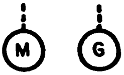
APPENDIX I—ELECTRONIC PARTS SYMBOLS—CONTINUED



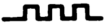
SEPARATELY EXCITED
DC GENERATOR OR MOTOR



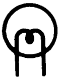
GYRO TORQUE MOTOR



MOTOR AND GENERATOR



HEATER
ELEMENT

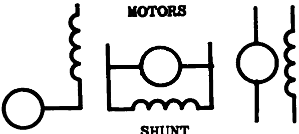


LAMP

METER

A - AMMETER
V - VOLTMETER
G - GALVANOMETER
MA - MILLIAMMETER
VA - MICROAMMETER
CRO - OSCILLOSCOPE

MOTORS

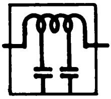


SERIES

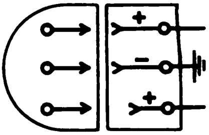
SHUNT

SEPARATELY
EXCITED

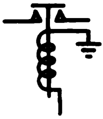
NOISE FILTER



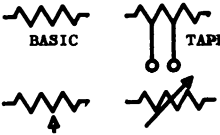
POWER RECEPTACLE



RELAY



RESISTOR



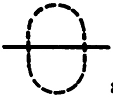
BASIC

TAPPED

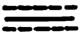
ADJUSTABLE

VARIABLE

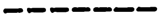
SINGLE
CONDUCTOR



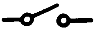
OR

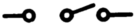


SINGLE
SHIELDED
CONDUCTOR

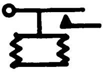
SHIELDING 

SWITCH

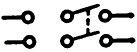




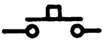
SPDT SWITCH



PRESSURE
SWITCH

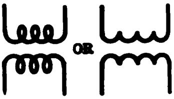


SWITCH DPDT

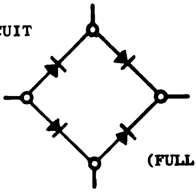


MOMENTARY

TRANSFORMER



BRIDGE CIRCUIT



(FULL WAVE RECTIFIER)

APPENDIX II

ANSWERS TO QUIZZES

CHAPTER 1

INTRODUCTION

1. b.
2. b.
3. d.
4. c.
5. a.
6. c.
7. b.
8. a.
9. c.
10. d.
11. d.
12. b.
13. d.
14. d.
15. b.
16. b.
17. a.
18. d.

CHAPTER 2

AVIATION BALLISTICS

1. c.
2. b.
3. a.
4. c.
5. d.
6. c.
7. d.
8. a.
9. b.
10. d.
11. c.
12. a.
13. b.

CHAPTER 3

AIRCRAFT GUN SYSTEMS

1. c.
2. d.
3. c.
4. c.
5. d.
6. b.
7. b.
8. c.
9. d.
10. b.
11. a.
12. c.
13. c.
14. d.
15. a.
16. d.
17. a.
18. b.
19. d.
20. a.
21. a.
22. b.
23. a.
24. d.
25. a.
26. d.
27. c.
28. d.

CHAPTER 4

AIRCRAFT BORESIGHTING

1. d.
2. d.
3. c.
4. a.
5. c.
6. d.
7. c.
8. a.
9. b.
10. d.
11. b.
12. c.
13. c.
14. b.
15. a.
16. a.
17. a.
18. a.
19. d.
20. d.
21. c.
22. c.
23. c.
24. d.
25. c.

CHAPTER 5

LINKING AND DELINKING EQUIPMENT

1. b.
2. d.
3. c.
4. a.
5. c.
6. b.
7. a.
8. c.
9. c.
10. c.
11. a.
12. b.
13. b.
14. c.
15. b.
16. b.

CHAPTER 6

AIRCRAFT TURRET SYSTEMS

1. d.
2. b.
3. d.
4. b.
5. c.
6. a.
7. d.
8. d.
9. a.
10. d.
11. c.
12. b.
13. d.
14. c.
15. d.
16. b.
17. d.
18. d.
19. a.
20. c.
21. d.
22. c.
23. c.
24. b.
25. c.

CHAPTER 7

SUSPENSION, ARMING, AND RELEASING SYSTEMS

1. c.
2. c.
3. c.
4. a.
5. b.
6. b.
7. a.
8. d.
9. d.
10. b.
11. c.
12. c.
13. a.
14. c.
15. d.

CHAPTER 8

BOMBING EQUIPMENT

1. c.
2. d.
3. a.
4. b.
5. c.
6. a.
7. a.
8. d.
9. c.
10. d.
11. b.
12. a.
13. b.
14. c.
15. d.
16. b.
17. a.
18. c.
19. d.

CHAPTER 9

SMALL ARMS RANGES

1. d.
2. b.
3. d.
4. c.
5. b.
6. a.
7. a.
8. d.
9. c.
10. d.
11. c.
12. b.
13. d.
14. a.
15. a.
16. d.
17. c.
18. a.
19. a.
19. a.
20. d.
21. b.
22. c.
23. d.
24. a.

CHAPTER 10

AMMUNITION HANDLING AND STOWAGE METHODS

1. d.
2. c.
3. a.
4. d.
5. c.
6. a.
7. b.
8. b.
9. a.
10. b.
11. c.
12. d.
13. d.
14. a.
15. d.
16. c.
17. c.
18. a.
19. c.
20. c.
21. d.
22. b.
23. c.
24. b.
25. c.

CHAPTER 11

ADMINISTRATION

1. a.
2. d.
3. d.
4. b.
5. c.
6. b.
7. d.
8. c.
9. c.
10. b.
11. a.
12. a.

CHAPTER 12

TRAINING AND SUPERVISORY TECHNIQUES FOR AVIATION ORDNANCE

1. c.
2. c.
3. a.
4. b.
5. d.
6. d.
7. c.
8. d.
9. d.
10. d.
11. c.
12. d.
13. b.
14. c.

APPENDIX III

QUALIFICATIONS FOR ADVANCEMENT IN RATING

AVIATION ORDNANCEMAN (AO)

RATING CODE NO. 6500

(Extracted from NavPers 18068 (Revised) through Change 8)

General Service Rating

Scope

Aviation Ordnancemen maintain, service, remove, repair, install, operate, and handle small arms and aviation ordnance equipment including aircraft guns, turrets, powered gun mounts, rocket launchers, suspension and release mechanisms, and pyrotechnic, tow-target, and munitions handling equipment; operate and perform routine servicing and checking of aviation gun, bomb, and rocket sights; stow, maintain, service, handle, install, and remove aviation munitions and pyrotechnics; maintain and operate a small arms range.

Emergency Service Rating

AVIATION ORDNANCEMEN U (Utility) Rating Code No. 6501 ------ **AOU**

Maintain, service, remove, repair, install, operate, and handle small arms and aviation ordnance equipment including aircraft guns, rocket launchers, and suspension and release mechanisms, pyrotechnic, tow-target, and munitions handling equipment; operate and perform routine servicing and checking of aviation gun, bomb, and rocket sights; stow, maintain, service, handle, install, and remove aviation munitions and pyrotechnics; maintain and operate a small arms range.

AVIATION ORDNANCEMEN T (Turrets) Rating Code No. 6502 ------ **AOT**

Maintain, service, remove, repair, install, and operate aircraft turrets and powered gun mounts.

Navy Enlisted Classification and Codes

For specific Navy enlisted classification codes included within his rating, see *Manual of Navy Enlisted Classifications*, NavPers 5105 (Revised), codes AO–6800 to AO–6899.

Qualifications for advancement in rating	*Applicable Rates*		
	AO	**AOU**	**AOT**
100 PRACTICAL FACTORS			
101 OPERATIONAL			
1. Preserve, depreserve, adjust, and install aircraft guns	3	3	3
2. Operate aviation munitions handling equipment	3	3	3
3. Assemble, adjust, and install aviation ordnance fuzes, pyrotechnics, and munitions normally used in own activity	3	3	-------
4. Stow, handle, and load aviation munitions, pyrotechnics, and aircraft-laid mines, observing local and general safety precautions	3	3	3
5. Install, remove, and perform preflight operational checks to gun cameras and their magazines in accordance with local instructions	3	3	3
6. Belt and calibrate aircraft gun ammunition	3	3	-------
7. Install, remove, adjust, and operate tow-target equipment	2	2	-------
8. Perform stray-voltage and circuit continuity safety check on aircraft armament circuits in accordance with current instructions	2	2	-------
102 MAINTENANCE AND/OR REPAIR			
1. Demonstrate safe and proper use and maintenance of measuring instruments and hand and power tools used for aviation ordnance installation, maintenance, and repair	3	3	3
2. Use working drawings, blueprints, and wiring diagrams in servicing, repairing, assembling, and installing aviation ordnance equipment	3	3	3

Qualifications for advancement in rating	*Applicable Rates*		
	AO	AOU	AOT
102 MAINTENANCE AND/OR REPAIR—Continued			
3. Select and demonstrate safe and proper use of all instruments furnished as general test equipment in own unit	3	3	3
4. Inspect, clean, lubricate, preserve, adjust, and replace minor parts of aircraft sight	3	3	3
5. Inspect, clean, lubricate, adjust, and preserve aircraft turrets	3		3
6. Inspect, clean, service, lubricate, adjust, preserve, depreserve, and perform authorized repairs to small arms and aircraft guns	3	3	
7. Inspect, clean, lubricate, preserve and perform authorized parts replacement, tests, and adjustments to aviation ordnance handling equipment, except automotive equipment	3	3	
8. Boresight and aline aircraft sights, guns, and gun cameras	2	2	2
9. Check, adjust, and/or aline aircraft bomb and rocket suspension and release equipment	2	2	
10. Demonstrate safe and proper use of specialized ordnance test equipment	2	2	2
11. Replace unserviceable parts, assemblies, or subassemblies; aline, test, and make required adjustments to aircraft turrets	1		2
12. Prepare charts and design templates for use in boresighting aircraft armament	1	1	1
13. Maintain and service aircraft gun ammunition linking and delinking equipment	C	C	

Qualifications for advancement in rating	*Applicable Rates*		
	AO	**AOU**	**AOT**
103 ADMINISTRATIVE AND/OR CLERICAL			
1. Maintain required inventory and performance records of aviation armament and ordnance equipment, munitions, and pyrotechnics	3	3	3
2. Use applicable publications and instructions for the handling, stowage, issue, maintenance, and operation of aviation ordnance and armament equipment, munitions and pyrotechnics	3	3	
3. Instruct in safety regulations and precautions pertaining to small arms and aviation ordnance	2	2	
4. Train and supervise personnel engaged in maintenance and repair of:			
a. Aircraft armament and aviation ordnance equipment	1	1	----
b. Aircraft turrets	1	--------	
5. Train and supervise personnel in proper handling of aviation munitions and pyrotechnics	1	1	----
6. Organize and administer facilities for maintenance and repair of aviation ordnance and armament equipment	C	C	
7. Supervise the use, filing, and maintenance of publications logs and records and the preparation of reports required by own activity	C	C	
8. Determine allowances; requisition, supervise, inventory of, and account for allowed materials in accordance with current directives	C	C	
9. Organize, instruct in, and conduct small arms firing practice	C	C	----

Qualifications for advancement in rating	*Applicable Rates*		
	AO	**AOU**	**AOT**
200 EXAMINATION SUBJECTS			
201 OPERATIONAL			
1. Safety precautions for handling and stowing aviation munitions, pyrotechnics, and aircraft-laid mines	3	3	3
2. Safety precautions to be observed in the use of aviation munitions, pyrotechnics, and ordnance equipment	3	3	-------
3. Types, nomenclature of parts, and assemblies of:			
a. Small arms and aircraft guns	3	3	3
b. Aircraft turrets	3	--------	3
c. Aircraft sights	3	3	3
d. Fuzes	3	3	-------
4. Types, operation, and components of aviation ammunition, bombs, rockets, fuzes, pyrotechnics, and JATO	3	3	-------
5. Procedures, sources of information, and safety precautions for belting and calibrating aircraft gun ammunition	3	3	-------
6. Functions of those components common to all aircraft equipment in each of the following groups:			
a. Aircraft noncomputing sights	3	3	3
b. Aircraft computing sights	2	--------	2
c. Bomb sights	2	--------	-------
d. Bomb directors	1	--------	-------
7. Operating characteristics of electrical and hydraulic aircraft turrets	2	--------	3
)2 MAINTENANCE AND/OR REPAIR			
1. Proper use of measuring instruments and of hand and power tools common to rating	3	3	3

Qualifications for advancement in rating	*Applicable Rates*		
	AO	**AOU**	**AOT**
202 MAINTENANCE AND/OR REPAIR —Continued			
2. Identify standard symbols found in electrical wiring diagrams of aviation ordnance equipment	3	3	3
3. Tests requiring use of simple ohmmeter, ammeter, and voltmeter	3	3	3
4. Determine values of voltage, current, and resistance in series and parallel resistor combinations	3	3	3
5. Cleaning solutions, lubricants, and preservatives used in maintenance of aviation ordnance and armament equipment	3	3	3
6. Procedures for determining and correcting malfunctions of aircraft guns	3	3	
7. Solve problems in:			
a. Square and cubic areas for storage and pressures	3	3	3
b. Ratio and proportion for hydraulics, pneumatics, and electricity	3	3	
c. Graph reading for ballistics and boresighting	2	2	
d. Substitution of known values in formula	2	2	
8. Procedures for adjusting and maintaining aircraft noncomputing sights	3	3	
9. Procedures, sources of information, and safety regulations for boresighting aircraft sights, guns, and gun cameras	2	2	
10. Procedures for localizing a defective component part in a circuit by means of measurement of voltage, resistance, and current	2	2	

Qualifications for advancement in rating	*Applicable Rates*		
	AO	**AOU**	**AOT**
202 MAINTENANCE AND/OR REPAIR —Continued			
11. Procedures for adjusting and maintaining aircraft bomb and rocket suspension and release equipment	2	2	-------
12. Procedures for adjusting and maintaining aircraft turrets and powered gun mounts	2	--------	3
13. Procedures and sources of information relative to the preparation of boresighting charts and templates	1	1	1
14. Practical application of the principles of internal and external ballistics to aviation ordnance	C	C	C
203 ADMINISTRATIVE AND/OR CLERICAL			
1. Purposes and types of entries made in maintenance and inventory records kept for aviation ordnance and armament equipment, aviation munitions, and pyrotechnics	3	3	3
2. Safety regulations and precautions pertaining to small arms and aviation ordnance and armament equipment	2	2	2
3. Types of information found in each of the following publications: OP, OD, OCL, OHI, OMI, OML, ORDALTS, NavAer Publications Index, Aircraft Armament Changes, and Aircraft Armament Bulletins	2	2	2
4. Use of applicable allowance lists, OP's, parts catalogs, and forms in the requisitioning, salvage, and survey of aviation ordnance materials	C	C	C
5. Procedures and regulations for conducting small arms firing practice	C	C	-------

Qualifications for advancement in rating	*Applicable Rates*		
	AO	**AOU**	**AOT**
300 PATH OF ADVANCEMENT TO WARRANT OFFICER AND LIMITED DUTY OFFICER Aviation Ordnancemen advance to WARRANT AVIATION ORDNANCE TECHNICIAN and/or to LIMITED DUTY OFFICER, AVIATION ORDNANCE.			

INDEX

Accelerometer, 355
Actual angle, 346
Adiabatic expansion, 37–38
Adjustments, M16 link loading machine, 212–219
Administration:
  aviation ordnance and armament supply, 473–487
    allowance lists and parts catalogs, use of, 484–487
    identification, 480–483
    Navy Supply System:
      distributive points, 475
      primary stock points, 475–476
      reserve stock points, 475
      secondary stock points, 476–480
    procedures for ordering material, 483–484
  logs, records, and reports, 492–494
  Navy Directives Filing System, 494–495
  publications, 488–492
  salvage and survey procedures, 495–498
    formal surveys, 496–497
    informal surveys, 497–498
Advancement, qualifications for, 17–19, 21–24
Aircraft boresighting:
  equipment used, 131–151
    Clearance Fixture Mk 1 Mod 0, 140–144
    Kit Mk 1, 131–140
    screens, 145
  miscellaneous considerations, 172–175
Aircraft boresighting—Cont.
  procedures, 151–172
  safety precautions, 175–178
  theory of, 126–131
    convergence, 131
    parallel, 130
    terminology, 127–130
Aircraft gun systems, 70–121
  gunfiring controls and charging systems, 70–104
    hydraulic fluids, 102–104
    hydraulic gun charger and controls, 85–102
    pneumatic gun charger and gunfiring controls, 71–85
  gun installation problems, 116–119
    ammunition chuting, 118
    feed difficulties, 116–117
    gun and camera mounts, 118–119
    link and case ejection, 117–118
  lubrication and preservation, 104–116
  safety precautions, 119–121
Allowance lists:
  NavAer, 485–486
  NavOrd, 486
  use of, 484–487
Ammunition:
  calibration, 117
  coding and code structure, 464–468
  electric primed, 239
  handling:
    afloat, 422–435
    ashore, 435–442
  inspection, 437

Ammunition—Continued
  jamming in chutes, 118
  receipt and deliveries, 424–429
  receipt and shipment, 419–420
  stowage requirements, 439–441
    bombs, 441
    inert components, 441
    pyrotechnics, 441
    rocket components, 441
    small arms, 441
Ammunition handling and stowage methods, 417–472
  general considerations, 417–422
    handling equipment, 420–421
    organization and personnel, 418–419
    receipt and shipment, 419–420
    records and reports, 421–422
    responsibilities, 417–418
  organization and procedures:
    advance bases, 442–448
    afloat, 422–435
    ashore, 435–442
  safety precautions, 448–457
    aircraft rockets, 454–455
    boosters, 455
    fixed ammunition, 456
    handling equipment, 453
    JATO, 455
    smoke ammunition, 456–457
    torpedoes, 457
  stock recording system, 457–468
    coding and code structure, 463–468
    description and procedures, 461–463
    purpose and scope, 457–461
Armament, 8-9
Arming device, 336
Arming systems, 321–340
  fighter type, 321–327
  attack type, 327–332
  patrol and ASW, 332–340
Armory and magazines officer, 425–426
ASW aircraft, 369
Attack, angle of, 155–156
Aviation ordnance and armament supply, 473–474
Aviation ordnance gunner, 429
Aviation ordnance officer, 428
Axis:
  bore, 127
  sight, 127

Backlash, turret, 270, 302
Ballistic coefficient, 346
Ballistics, aviation, 28–67
  exterior, 40–67
    aircraft motion, 57–58
    air resistance, 53–55
    comparison of vacuum and still air trajectories, 62–67
    drift and precession caused by rotation, 49–52
    gravity, 53
    jump, 59–60
    projectiles in flight, photography of, 43–46
    rotation of projectile, 48–49
    trail, 58–59
    trajectories, 46–48
    underwater, 52–53
    wind, 55–57
    yaw, 60–62
  interior, 30–40
    adiabatic expansion, 37–38
    combustion, 33
    erosion, 38–40
    explosives, 30–31
    heat cracks, 38
    ignition, 31–32
    propellants and charges, 33–36
    service life of gun, 40
    temperatures, 34–37
Billets, Aviation Ordnanceman, 12–17
Bomb directors, 353

Bombing:
  devices, employment of, 363–369
    installation in aircraft, 367–369
      ASW, 369
      attack, 368
      fighter, 367–368
      patrol, 368
    tactical uses:
      dive, 363–364
      glide, 364–365
      high altitude, 365–366
      loft, 365
      low altitude (LAB), 366
  directors, 353–362
    high altitude, 352–356
    low altitude, 357–362
  radar, 350–353
    purpose, 350
    results, 351–353
  theory of, 343–350
    drift, 347–350
    in a vacuum, 343–347
Bomb shackle, 330, 339
Boosters, ammunition, 237–242, 259–260
Boresighting, turret guns, 260–261
Boresight Kit Mk 1, maintenance of, 140
Brackets:
  boresight, 127, 160–161
  clutch, 187
  Geneva, 187
Brakes, turret solenoid-operated, 264
Bulletin of Ordnance Information, 489
Bureau of Ordnance Instructions, 418
Bureau of Ordnance Manual, 418
Bureau of Supplies and Accounts Manual, 484
Bureaus:
  Aeronautics, 6–7
Bureaus—Continued
  Ordnance, 5–6
  Supplies and Accounts, 477
Bus, master armament, 321

Calibrator, 355
Camera, turret gunsight recording, 251, 253–255
Catalog of Navy Material, 489
Combustion, 33
Compressor, turret pneumatic, 237, 251, 252
Computing circuits, 351
Controller, turret, 229, 244–245
Control panel, 361
Corrosion:
  direct chemical attack, 105
  electrochemical action, 106
Cross trail, 63–64, 347
Course A, 382
Course C, 384
Course K, 381

Datum line, boresight, 127
Datum point, boresight, 128, 150
DD Form 1150A, 493
Deflection, 57–58
Departmental or bureau specifications, 111
Distinguished marksman, 410
Distribution points, 474
Dither mechanism, turret hydraulic, 298, 306
Drift, 347–350
Drift angle, 63–64
Dropping angle, 346
Dry cleaning solvent, 116

Ejector racks, 327, 339
Emergency release device, 330, 334
Equipment, ammunition handling, 420–421
Erosion, 38–40
E-transformer, turret, 288–292
Explosives, 30–33

Federal specifications, 111
Feed mechanisms, turret, 257–259, 299
FIIN, 481
Firing procedures, 392
Fixture, Clearance, Mk 1 Mod 0, 140–144
Flight attitude, 127
Formal survey, 496
Forward velocity of bomb, 352
Fueling, inflight, 339

Gallery rifle target, 398
Geneva bracket, 187
Geneva crank, 193
Glide bombing, 364
Gravity, acceleration of, 344
Gun and camera mounting trends, 118
Gun camera, boresighting of, 163–165
Gun driving springs, weakening of, 94
Gunnery officer, 424
Gyroscope, turret stabilizing, 288–293
Gyroscope, vertical, 354
Gyroscope, yaw-roll, 355

Handling equipment, munitions, 453
Handwheel drive assembly, 191–192
Hard film corrosion preventive compound, 113
High pressure air, defined, 81
Holding circuit, defined, 86
Horizontal closing rate, 352
Hydraulic fluid:
  additives, 102
  contamination of, 103
  film strength, 103
  ideal, 102
Hydraulic gun charger and controls:
  components, 85–102
Hydrolube, 104

Indoctrination and instruction, 389–396
Inflammation, 31–32
Informal survey, 497
Interrupter:
  gunfire, 141, 247, 266
  structural, 140, 246–247, 267

JATO equipment, 331
Jump, angle of, 59–60
Junction box:
  turret control, 250
  turret main, 247

Kit, Boresight, Mk 1, 131–140

LABS, 353
Lead:
  ballistic, 231–233
  kinematic, 231–233
Leadership, 504–508
Learning and learning processes, 511–513
  trial and error, 511–513
Lights, turret:
  indicator, 264–265
  trouble, 264–265
Linking and delinking equipment, 183–222
  M16 link loading machine:
    adjustments, 212–220
    description, 186–199
    operating and maintenance, 205–212
    operation, 199–204
  safety precautions, 220–222
Logs, records, and reports, 492–494
Low temperature grease, 114
Lubrication:
  aircraft guns, general rules for, 110
  M16 link loading machine, 211–212

Lugs, leveling, 128, 159–160

M1 Garand rifle, 381
M16 link loading machine:
  adjustments, 212–219
  description:
    ammunition tray, 198
    base assembly, 186–187
    clutch bracket, 187
    clutch shaft assembly, 192
    delinker assembly, 198–199
    drive assembly, 189
    drive shaft assembly, 190–191
    electric motor, pulley, and belt, 189–190
    feed arrangement, 196–198
    Geneva bracket, 187
    Geneva crank, 193
    handwheel drive assembly, 191–192
    loading wheel:
      front support, 187–188
      guide bracket, 189
      unit, 194–195
    pusher mechanism and housing, 193–194
  maintenance, 205–220
  operation, 199–204
  safety precautions, 220–222
Master armament switch, 325–327
Mechanisms:
  pusher, 194, 201
  vibrator, 197, 203
Medium preservative lubricating oil, 115
Methods of instruction, 509–511
  demonstration, 510–511
  discussion, 509–510
  lecture, 509–510
Mil, 129, 144
Military leadership, 505–509
Military specifications, 111
Motor-generator, 242
  tests, 271–275
Motors, turret drive, 243, 255–256
Mounts, gun, 260
Munitions, return of, 429–431
Magazines, 432–433
  data, 439
  symbols, 437–439

Naval Aeronautical Supply Organization, 480
Naval Aeronautic Publications Index, NavAer 00–500, 485
Naval Aviation News, 489
NavOrdInst 5213.1, 493
NavOrd Instructions, 402
NavOrd Lists, 402
Navy Directives Filing System, 494–495
Navy Emergency Ground Defense Force (NEGDF), 395
Navy Stock Fund, 478
Navy Supply System, 474–487
NRL lubricant, 114
Numbers in parentheses, association of with schematic diagrams, 70

Offsets, boresight screen:
  horizontal, 145–146, 150
  vertical, 145–146, 150
OP 0, *Index of Ordnance Publications*, 442
OP 4, *Ammunition Afloat*, 418
OP 1675, *Ammunition Stock Recording Procedures Manual*, 468
OP 2165, *Transportation of Ammunition and Explosives*, 419
OpNav 34P1 *U. S. Navy Safety Precautions*, 418
Ordering materials, procedures for, 483–484
Ordnance Circular Letters, 494
Ordnance Handling Instructions, 494
Ordnance Material Letters, 494

Ordnance officer, 425
Ordnance Pamphlet 5, 418–439
Ordnance Technical Instructions, 494
Ordnance Supply Officer, 480
Organization and procedures for advance bases, 442–448
Organization, aviation ordnance, 2–3
Organization of ranges, 373–378
Oxidation, 106

Parallax, 129, 149
Parts catalogs, use of, 484–487
Periscope, 362
Personnel relationship, 517–518
Pigtail, 326
Pistol marksman, 379
Place badges, 409
Pneumatic gun charging and controlling system:
  components of, 74–85
Pneumatic system lubricating grease, 113
Power distribution:
  attack aircraft, 329
  fighter aircraft, 321
Power, electric drive turret requirements, 233, 235–241
Preparatory exercises, 390
Preservatives:
  application of, steps in, 105
  choice of proper types, 108
  methods of, 107
Primary stock points, 474
Principles of supervision, 515–517
Propellants, 33–35
Projectile, forces action on:
  aircraft motion, 57
  air resistance, 53–55
  drift, 49–51
  gravity drop, 53
  precession, 51–52
  rotation, 48–49
  wind, 55–57
Publications, 488–492
  logs, records, and reports, 487–494
  reference, 19–24
Pumps, hydraulic turret, 296–298, 305
Pusher mechanism, 194, 201

Qualities of a good supervisor, 518–519

Racks:
  bomb, 339
  ejector, 327
Radar indicator, 351
Ranges, small arms, 373–412
  ammunition for, 401–403
  indoctrination and instructions, 389–396
    firing procedures, 392–395
    preparatory exercises, 390
    small arms employment, 395–396
  organization of:
    authority for installation, 373–378
    employment of, 375–378
  safety precautions, 411–412
  small arms firing, 396–398
    regulations and responsibilities, 396–398
  targets, 398–401
    maintenance and employment of, 399–401
    material, 399
  types of, 378–389
    automatic weapons, 382–386
    pistol, 379–380
    rifle, 381–382
  records, reports, and medals, 403–411
Ranges, types of, 378–389
Rates, aviation ordnance
  AO, 3–4
  AOT, 4
  AOU, 4

Rates, aviation ordnance—Cont.
  emergency service, 4–5
Receivers, turret:
  azimuth, 243–244
  elevation, 243–244
Records and reports, ammunition, 421–422, 442
Records, reports, and medals, 403–410
Regulator, voltage, 241–251
Relay, master turret, 252
Relay, turret time delay, 237–238, 262
Release systems, 321–340
  attack type, 327–332
  fighter type, 321–327
  patrol and ASW, 332–340
Reserve stock points, 474
Responsibilities, Aviation Ordnanceman, 9–12
Responsibility of leadership, 516–517
Retro-ejector, 335
Revolver expert, 380
Rifle bore cleaner, 112
Rocket package switch, 325

Safety precautions, 411–412
  ammunition and explosives, 448–452
  knowledge of, 119
  M16 link loading machine, 220–222
Salvage and survey procedures, 495–498
Screens, boresight, 145–151, 173–174
Searchlight, 249–250
SecNavInst 5215.1A, 495
Secondary stock points, 474
Service records, 405
Shackles:
  bomb, 330, 339
  ejector, 339
Sharpshooter, 410
Ship's gunner, 426–427
Sight angle, 128
Sighting angle, 346
Slant range, 352
Sliprings, turret, 233
Small arms:
  ammunition, 401–403
  firing, 396–398
  records, 403
  reports, 405
  targets, 398–401
Soft film corrosion preventive compound, 112
Special low temperature oil, 115
Special preservative lubricating oil, 114
Specific precautions of munitions, 452–457
Stabilization, electric turret, 288–293
Stabilizing unit, 362
Station development board, 373
Station status indicator, 337
Supervisory and training techniques, 503–519
Supply-demand control points, 479
Surface treatment processes, 109
Suspension, arming, and releasing systems, 319–340
  attack, 327–332
  fighter, 321–327
  patrol and ASW, 332–340
Sway braces, 340
Switches:
  arming, 323
  control stick, 329
  emergency (turret systems), 235, 261
  master armament, 325
  master turret, 228
  rocket package, 325
  selector, 324, 325, 327, 337
  special, 334
  trigger, 238–239, 245–246
  turret action, 228–229
  turret limiting, 263

Templet, boresight, 130
Terminal velocity, 65, 348
Time of fall, 61, 63
Time of flight, bombs, 352
Timer, 354
Tracking control, 359
Tracking data computer, 358
Trail, 58–59, 63, 344
  angle of, 66
Trail angle, 346
Training and supervisory techniques, 501–519, 503–504
Trajectories, 46–48
Trajectory drop, 128
Trajectory, vacuum, 344
Transmitters, turret, 243
Turret systems:
  electric drive, 228–294
    alignment, 283–288
    components, operation of, 233–268
Turret systems—Continued
  electric drive—Continued
    lead computation, theory of, 231–233
    maintenance, 268–271
    operation, theory of, 228–231
    repairs, 279–283
    stabilization system, 288–293
    tests, 271–279
    ventilation systems, 293–294
  electrohydraulic drive, 294–314
    operation, theory of, 294–307
    safety precautions, 307–314

Vacuum range, 344
Ventilation, turret systems, 293-294
Vibrator mechanism, 197, 203

Water repellent composition, 116

Yaw, projectile, 60–61

☆U. S. GOVERNMENT PRINTING OFFICE: 1958—439443

14 DAY USE
RETURN TO DESK FROM WHICH BORROWED

LOAN DEPT.

This book is due on the last date stamped below, or on the date to which renewed.
Renewed books are subject to immediate recall.

20May'59VD	
REC'D LD	
MAY 7 1959	

LD 21A-50m-9,'58
(6889s10)476B

General Library
University of California
Berkeley

YB 7590